Alaska Sea Grant Program

AN EVALUATION OF THE ECONOMIC FEASIBILITY OF POLLOCK PROCESSING IN SOUTHEAST ALASKA

by

John Barrett Martin

A THESIS
submitted to
Oregon State University
in partial fulfillment of
the requirements for the
degree of
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ABSTRACT

An economic feasibility analysis of processing Alaska pollock, (*Theragra chalcogramma*), was conducted, and the results reported as the wholesale pollock block prices at which the present value of the investment in pollock processing facilities equals zero. These break-even block prices were compared with current market prices of pollock blocks, and it was found that pollock processing is economically feasible under all sets of assumptions evaluated.

A case-study of the Icicle Seafoods, Inc. (ISI) plant at Petersburg, Alaska was undertaken in this work. ISI was the only domestic seafood processor handling pollock at the initiation of the research.

Economic feasibility research in three subject areas is reviewed: (1) food processing, (2) aquaculture, and (3) seafood processing. The aspects of each study relevant to pollock processing feasibility are emphasized.

Some of the more critical sources of uncertainty with which a pollock processor must deal are explained. Supply variability is found to be the most significant source of uncertainty, although pollock markets, new technology, and the institutional environment are also important sources of uncertainty for the processor.

Various measures of investment worth are evaluated. The Net Present Value (NPV) technique is chosen as an economically valid investment criterion and used in this research. Due to the supply variability problem, future volumes of production cannot be accurately predicted. The triangular distribution function and Monte Carlo simulation methods are used to generate probability distributions of volumes over the ten-year investment horizon. Wholesale pollock block price projections over the next ten years were not available to the researcher. Therefore the NPV equation was solved for the pollock block price at which the NPV of the investment equals zero, for a given set of assumptions.

Results include distributions of the break-even pollock block prices under various production, cost, and discount rate assumptions. The break-even block prices are very sensitive to changes in ex-vessel prices, but quite insensitive to changes in the discount rate. It is found that the current market price exceeds the break-even block prices under all sets of assumptions, and concluded that pollock processing appears to be economically feasible.

Finally, it is noted that the results of the analysis depend vitally on the production cost estimates provided by the personnel of ISI. It is recognized that relying on information from a single firm will produce results which are to some extent unique to that firm. The assumption was made that these results can be used as order-of-magnitude estimates of the expected costs and returns to other seafood processors in S.E. Alaska entering pollock production.

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TABLE OF CONTENTS

Table of Contents -- continued

LIST OF TABLES

LIST OF APPENDIX TABLES

LIST OF FIGURES

AN EVALUATION OF THE ECONOMIC FEASIBILITY OF POLLOCK PROCESSING IN SOUTHEAST ALASKA

I. INTRODUCTION

On March 1, 1977 the Fisheries Conservation and Management Act of 1976 (FCMA) became law. This act extends U.S. fisheries jurisdiction from 12 to 200 miles offshore. One of the implications of this act is that the U.S. now has the authority (albeit unilateral) to manage groundfish resources within 200 miles of the U.S. coastline.[1] The FCMA specifies that these groundfish resources be managed by the regional councils to provide optimum yields. Prior to implementation of the FCMA, U.S. seafood producers were reluctant to invest in certain groundfisheries, for fear that the fish stocks could be depleted by the fishing fleets of foreign nations. Since jurisdiction over these stocks has been unilaterally declared by the U.S., this depletion should not occur given effective implementation of the FCMA. This fact, coupled with the recent upward trends in wholesale prices of groundfish products, has generated much speculation and interest as to the possibility of domestic harvesting and processing of groundfish in Alaska.

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[1]Groundfish is a general term for various species of flatfishes, roundfishes, and rockfishes which live on or near the ocean bottom.

Interest in developing fisheries for groundfish in Alaska is evidenced by the fact that as of September 1977, nine companies have either begun purchasing groundfish species or are planning to do so. Two companies, New England Fish Company (NEFCO) and Icicle Seafoods, Inc. (ISI) have entered into contracts with the Alaska Department of Commerce and Economic Development (ADCED) to begin processing operations. The ISI contract began on March 1, 1977, and the NEFCO contract on May 1, 1977. The ADCED has granted each of two firms $145,000 at the outset of the contract to be used for investment in groundfish processing facilities. At the end of the contract period, December 31, 1978 for both firms, if total income from groundfish operations exceeds the total costs calculated, the company is to repay the $145,000 to the ADCED. If the costs exceed the income from groundfish processing operations, the amount of the loss is subtracted from the $145,000 and that amount repaid to ADCED. Payments to the firms are not to exceed an amount equal to 3¢/pound of raw product purchased from the fishermen. ISI began processing operations during the spring of 1977 at its Petersburg, Alaska plant, while NEFCO started groundfish processing at Kodiak during December of 1977.

Fisheries development is an integrated process in which the various components all contribute to establishment of the milieu necessary for development to take place. Four principal components of fisheries development are: (1) resource availability, (2) harvesting capability, (3) processing capacity, and (4) established markets for the final products. A complete investigation of a fisheries development problem would seek to provide information pertaining to each of the above four components.

This investigation focuses upon the development of a fishery for Alaska pollock, *Theragra chalcogramma*, the species of groundfish which represents the largest exploitable biomass in the North Pacific. Pollock have been harvested extensively by foreign fleets in recent years. However, U.S. producers have exhibited little interest in pollock, due at least in part to the lack of fundamental information on the costs of harvesting and processing pollock in Alaska. Before large scale domestic investment can occur, it needs to be demonstrated that U.S. processors can earn a sufficient return on this high volume, low unit-value species. It is the objective of this research to provide information pertaining to the expected costs and returns to a domestic shore-based pollock processing operation.

Of the four components of fisheries development mentioned above, this work focuses on component (3), the processing sector. More specifically, this research tests the hypothesis that pollock processing in S.E. Alaska is economically feasible. Pollock processing is defined to be economically feasible if the returns from the sale of pollock exceed all costs incurred to establish and operate a processing facility, using an acceptable measure of investment worth to compute costs and returns.

In order to test the hypothesis that pollock processing in S.E. Alaska is economically feasible, the case-study approach is utilized. An in-depth study of the pollock operations at the Petersburg, Alaska plant of ISI is undertaken for two reasons. When the research was begun, ISI was the only U.S. seafood firm processing pollock in Alaska. Secondly, ISI has entered into a contract with the ADCED. The contract specifies that processing cost information from pollock operations be made public in the form of a report on commercial feasibility. This research partially fulfills Oregon State University contract obligations with ADCED to prepare said report on economic feasibility.

A partial-budgeting framework is used to delineate the effects on costs and returns to a seafood processing firm of investing in pollock processing facilities. The Net Present Value (NPV) investment criterion is selected as a valid and straightforward measure of investment worth, and is used to evaluate the investment decision. Several sources of uncertainty with which a pollock processor must deal are introduced and discussed. The most significant uncertainty is seen to be supply variability. For this reason, future volumes of production cannot be predicted with confidence.

Consequently, the triangular distribution function and Monte Carlo simulation methods are used to generate probability distributions of volume streams over the ten-year investment horizon. Finally, due to the unavailability of wholesale pollock block price projections, the NPV equation is solved for the wholesale block price which sets the NPV of the investment equal to zero, under different sets of assumptions.

It is necessary to make several assumptions in order to test the hypothesis that pollock processing is economically feasible. Initially, the contract with ADCED signed by ISI specifies that indirect costs are to be designated at 2¢/pound of raw product, and that the sales cost of marketing pollock is 5% of gross revenues received. The assumptions made pertaining to pollock processing operations are: (1) that the estimates of production costs, based upon limited production during the course of the research, are representative of the actual costs of production, (2) that the yield percentages used for the various stages of production are appropriate, and (3) that of the total raw product landed, 70% will be used for block production and 30% for headed and gutted production. The assumption is also made that demand will not be a limiting factor in the development of a domestic pollock industry. This means that pollock producers will be able to market at the current market price all pollock products produced. Finally, it is recognized that a case-study of one firm will generate results which are to some degree unique to that particular firm. The assumption is made in this research that these results can be used as order-of-magnitude estimates of the expected costs and returns to other seafood processors in S.E. Alaska entering pollock production.

The results of the analysis reflect the economic conditions pertaining to a single seafood processing firm. These results thus depend upon the assumption that factor prices (prices of raw product, labor, utilities, etc.) to the firm are constant. Should further entry into pollock processing occur, factor prices may not in fact remain constant. This research therefore addresses the issue of the economic feasibility of pollock processing for a single firm, and not for a pollock processing industry in general.

In Chapter II the literature pertaining to economic feasibility studies of fish and other food processing enterprises is reviewed. The sources of uncertainty with which a pollock processor must deal are discussed in Chapter III. In Chapter IV the research methodology utilized in this work is explained. The availability of the pollock resource in S.E. Alaska is evaluated in Chapter V, followed by a description of U.S. pollock markets in Chapter VI. The results of the economic feasibility analysis are presented in Chapter VII. Finally, a summary and the concluding remarks are provided in Chapter VIII.

II. REVIEW OF ECONOMIC FEASIBILITY RESEARCH

An economic feasibility study is an essential component of the information required in preliminary investment planning. It should be emphasized, though, that economic feasibility cannot suffice as the sole criterion in investment decision-making. In most instances it is necessary to demonstrate the biological, technical, or even political feasibility of a proposed project as well as the economic feasibility before a proposal can be declared viable. Although this work focuses principally on the economic uncertainties of groundfish processing, these other factors must be considered when addressing alternate aspects of groundfish development.

Economic feasibility analyses can serve three purposes. They can be utilized by private businessmen in evaluating investment proposals. These proposals can take the form of expansion of existing facilities, initiating production in a new geographical area, or development of new product forms. Second, feasibility analyses can be used by local governments in community or regional development planning. And third, economic feasibility studies can be used at the state or national level in making resource allocation decisions.

In reviewing the current literature relevant to the issue of the economic feasibility of a seafood processing plant, the author found published studies to fall into one of three categories: (1) economic feasibility of food processing plants, (2) economic feasibility of aquacultural enterprises, and (3) the economic feasibility of seafood processing plants. It is the author's opinion that useful insights into the techniques of feasibility analysis can be gained from studies in each of these categories. For purposes of clarity, then, the studies are grouped into the above categories and reviewed therein.

Food Processing Studies

The economic potential for a fruit and vegetable processing plant in Southern Oregon was examined by Groder in 1964 [17]. The first factor looked at was the ability of local agricultural production to support a proposed facility. It was determined that sufficient land was available, and that labor could be obtained for expansion of production. Labor for a processing plant was also found to be available. Existing buildings could be converted to provide facilities, and utilities and sufficient transportation services were also available. In short, the infrastructural requirements were satisfied.

A product mix was then selected based on a number of factors: past experience, market potential, the possibility of utilizing equipment for more than one product, and the length of operating season. Costs and returns were then estimated for two hypothetical plant sizes. The percentage return is calculated in two ways, the return on the total investment and the return on owner's equity. The results indicate the larger plant earning a higher percentage return, suggesting that economies of scale do exist.

This study serves to elucidate the general procedure followed in a feasibility analysis. The process of assessing the availability of the various factors of production is essential in any work of this nature. The study does possess one limitation, though. This is the use of the Return on Investment (ROI) evaluation of investment proposals. The principal criticism of the ROI method is that it does not take into consideration the timing of capital benefits and outlays. Thus incorrect management decisions can result due to the failure to take into account the time value of money.

Brooker and Pearson [10] have looked at the requirements for establishing plants to freeze vegetables in the Southern U.S. Vegetable production in this area has traditionally been for the fresh market. Expansion into processing requires: (1) availability of raw product, (2) the ability to operate processing plants efficiently, and (3) markets for the processed products. The authors assume that sufficient raw products are available and that demand exists for the processed products. The emphasis of the analysis, then, is on processing plant efficiency.

Six vegetable crops are considered for freezing: green beans, lima beans, leafy greens, okra, southern peas, and squash. Hypothetical single product plants are modeled and costs and returns evaluated at: five hourly output capacities, three processing season lengths, two raw product prices, and two finished product prices. The results show that annual net revenue was positively related to both plant size and length of processing season, indicating that economies of scale are present in both cases.

Profitability was evaluated using a discounted cash flow method. A planning horizon of 10 years and a discount rate of 10% was used. Annual net revenues were assumed constant throughout the 10 years. A plant was judged profitable if the discounted net returns over 10 years plus the discounted salvage value was greater than the initial investment.

The types of assumptions made by Brooker and Pearson regarding raw product and demand are quite similar to those employed in the analysis of pollock processing. In addition, looking at plants of various sizes, varying season lengths, and using different input and output prices are techniques basic to any feasibility study. Finally, the use of a net present value decision criterion is equally appropriate for seafood processing as well as food processing.

Hammond and King [20] have investigated the possibility of establishing a sweetpotato canning industry in North Carolina. North Carolina is the nation's second largest producer of sweetpotatoes, and much of the existing crop is off-sized and not suitable for the fresh market. Presumably this would provide sufficient supplies for a processing plant.

The authors posit four possible criteria for evaluating profit maximization: (1) Net Present Value, (2) the ratio of the present value of returns/present value of costs, (3) Rate of Return on Equity, and (4) Internal Rate of Return. The Net Present Value criterion is chosen for reasons of simplicity and the fact that it focuses on the entire life of the plant, not a particular production period.

An engineering-economic approach is used to estimate the capital and operating costs for four sizes of model plants. Each plant size is evaluated at three percentages of trim and peel loss and a range of season lengths. Then the calculations for each plant size are examined for sensitivity to varying input prices, output prices, and the discount rate. It was shown that the Present Value of the Investment was an increasing function of size of canning plant and length of season.

Hammond and King provide a useful discussion of various measures of investment worth. The Net Present Value criterion employed by Hammond and King is also utilized in this research to evaluate the investment in pollock processing facilities.

Aquacultural Studies

In a report published by Sea Grant at the University of Alaska [29], F. L. Orth has examined the economic feasibility of private non-profit salmon hatcheries in that state. Orth notes that feasibility is affected by two factors: ill-defined property rights leading to a potential free-rider problem and uncertainty regarding return of salmon and future market conditions. Due to the common-property nature of salmon stocks, Orth defines three levels of economic feasibility for a hatchery firm. Level one considers benefits to the hatchery only from the sale of surplus salmon. Level two considers benefits to include assessments from fishermen and processors as well as internal hatchery revenues. Level three, not evaluated in this paper, considers induced regional benefits in addition to those of level two.

Orth uses a net present value analysis to evaluate feasibility under varying assumptions as to productivity, price, discount rate, and operating costs. In addition to the long-run present value analysis, Orth undertakes an analysis of per-unit costs in the short run. The result of the calculations is that at level one the private hatchery is not economically feasible, and that some degree of subsidies or assessments are required by the hatchery firm to cover the opportunity costs of all its inputs.

There are several aspects of the above analysis relevant to the question of feasibility of pollock processing in S.E. Alaska. Orth based his cost estimates on a pilot project, comparable in many ways to Icicle Seafood Inc.'s pilot project with pollock. The author points out that statements of feasibility are not intended to focus specifically on one firm, but to identify the principal issues involved. The fact that a pilot project, in the initial year of production, utilizing new technology, may not produce entirely representative results must be recognized. However, the results generated will at worst be order-of-magnitude estimates of considerable value to decision-makers now faced with a paucity of reliable information.

In a study undertaken at Oregon State University, Im, *et al.*, [23] have examined the economics of hatchery production of Pacific Oyster (*Crassostrea gigas*) seed. This study focuses on two issues of seed production, estimating the demand for Pacific Oyster seed and explicating seed hatchery production costs. The demand equation is generated using econometric techniques while detailed process charts serve to identify uses of resources in production.

Costs per bushel are estimated for two plant sizes. The authors conclude that under certain restricting assumptions, the larger plant could produce seed at less than the current market price, and hence would be economically viable.

The aspects of this work most valuable to a feasibility analysis of pollock processing are the techniques used in the production cost analysis. In particular, the process charts are a useful tool to elucidate the details of a production process. The breakdown of production costs by stages of operation assists managers in identifying cost components of a system, and indicates the areas where improvements in efficiency would result in the greatest cost savings.

An evaluation of the commercial feasibility of salmon aquaculture in Puget Sound was conducted by Richards, _et al._, [31] in 1972. In their work the authors use a pilot commercial operation to examine the feasibility of rearing salmon to market size in salt water pens. Two methods of cost-revenue analysis are employed. The first method assigns an opportunity cost to all inputs utilized in the production process. Any net return above costs is then a return to uncertainty or management. An alternate method uses a discounted cash flow approach, generating the present value of the investment or rate of return on capital.

A 10% opportunity cost is used in the initial method. Costs are allotted to each discrete stage of the production cycle, and the total production cost/pound of salmon is determined. Using an estimated market price, returns to the salmon grower are projected to be 10% above opportunity costs. The authors stress that due to uncertainty in both production and marketing, a high initial yield may be necessary to attract investment. As the uncertainty is reduced, entry into the industry can be expected to reduce returns above the opportunity costs of inputs.

The alternate method of evaluating the venture, discounting to a present value, presents similar results. Using the same market price for salmon, the expected yield on investment is about 20%.

The significance of this work to pollock feasibility analysis lies in the fact that evaluation of a pilot commercial venture was undertaken. The authors' contention that a relatively high return (20%) may be required by investors due to extreme uncertainty may pertain to potential pollock processors as well. In addition, the authors note that a pilot project generates only preliminary information and that further analysis, especially in the area of marketing, must be done to draw definitive conclusions.

The economic feasibility of raising giant prawns (*Macrobrachium rosenbergii*) has been studied by Shang at the University of Hawaii [32]. Shang uses a net present value approach to evaluate investment worth. He also manipulates the net present value equation to derive an expression for the break-even price required by the fish farmer. Shang performs a detailed cost-revenue analysis for each of two separate stages of raising prawns, juvenile prawn production and prawn farming itself. The calculations for prawn farming are performed at two different levels of production, four separate farm sizes, five discount rates, and three levels of price. The results indicate that economies of scale do exist in that the break-even price is much lower for the larger farm sizes. Shang concludes that the future of prawn farming ultimately depends on the market for prawns in the mainland U.S.

Again, the aspects of this analysis relevant to the evaluation of the feasibility of pollock processing are: (1) use of net present value as a decision criterion, and (2) the use of a range of discount rates to allow for uncertainty.

Seafood Processing Studies

Holmsen and McAllister [22] at the University of Rhode Island have examined both the technological and economic factors involved in harvesting and processing an underexploited resource, deep sea red crabs (*Geryon quinquedens*). They indicate that the first requirement is resource availability. Once resource availability has been established, the harvesting technology must be developed. Next, the authors state that expected returns from crabbing must be at least as great as those from alternate fisheries during the same months. Via this opportunity fishery approach they arrive at a minimum ex-vessel price crabbers must receive for crabbing to be economically viable. Next the technology associated with processing is illustrated. Then, based on yield and labor productivity estimates, the minimum price the processor must receive for his product is generated for various input or ex-vessel prices. The authors maintain that the above process is sufficient to arrive at a first approximation of the feasibility of red crab processing.

The work of Holmsen and McAllister is relevant to the problem of assessing the feasibility of pollock processing in the following ways. First, the general approach to development of an underutilized fishery resource is much the same as the approach taken in this work. Second, the authors point out that in a developing fishery there are likely to be many initial problems. Through a process of trial and error both fishermen and processors need to establish the most efficient methods of accomplishing their objectives. Third, processors will probably have to deal with irregular supplies of fish and untrained labor. Consequently, the costs of operation are expected to be initially rather high and decline as more experience is gained handling the product.

During the 1960's there was much interest in the development of a fish protein concentrate (FPC) industry in North America. At that time Holder, et al., [21] published a report on the economics of a commercial FPC operation. The authors estimated production costs for a range of plants handling from 25 to 200 tons/day of whole fish, at a price of \$.01-\$.06/pound. Emphasis is placed on the high risks and developmental costs of such an operation. A list of factors affecting feasibility is provided. Among the most important are: plant location, method of assessment of feasibility, determination of risks, fish reserves and quality, harvest techniques, availability of management personnel, the product form and transportation costs.

FPC represents approximately 15% of the raw fish weight. Because of this low yield, the cost of the product is extremely sensitive to the cost of raw product. In fact, the authors conclude that the price of fish is the single most important item in the feasibility calculations.

In 1974 a study was undertaken by the Coos-Curry-Douglas (CCD) economic improvement association to determine the economic feasibility of a fishmeal plant on the Southern Oregon Coast [12]. The report looks at characteristics of the current fishmeal industry, the factors influencing future demand for fishmeal, and at the potential sources of raw product, prior to conducting the actual feasibility analysis of a fishmeal plant. The feasibility evaluation is made for plants of four output sizes, various combinations of public and private financing, and several sources of raw product supply. Capital and operating costs for each plant are estimated based on the best available information. Annual revenues are then estimated at various prices for fishmeal.

The results indicate that the larger plants would probably be economically feasible if they could secure a stable source of raw product supply. The authors point out that two prior attempts to establish reduction plants in Washington failed due to the inability to assure regular supply. The CCD study suggests two possible methods of remedying this situation, the plant owning and operating the vessels and explicit contracts with local fishermen to provide fish to the plant. As will be detailed below, the supply of fish to the plant is critical for pollock processors as well. Assuring stable sources of raw product is one of the foremost tasks of the potential pollock processor.

A market research study was conducted for the U.S. Department of Commerce in 1965 to assess the prospects for an Alaskan bottomfishery [36]. The study focused on the ability to market bottomfish products, assuming a dependable supply and price competitiveness. Although the validity of these assumptions may be challenged today, some useful conclusions are reached.

To evaluate resource potential, the authors utilized the then recently published survey data by Alverson, Pruter, and Ronholt [1]. It was found that pollock were the most abundant roundfish between Juan de Fuca Strait and Cape Spencer. In the range from 50-199 fathoms, pollock represented 36-54% of the roundfish in this region.

The authors express that if an Alaskan bottomfish industry were to develop, it must be a highly efficient operation. The structure must be different than the small vessel, hand processing nature of the existing West Coast bottomfish industry.

This report also stresses the importance of producing high quality fillets in regular, consistent supplies. The most promising markets are identified as the Mid-West and Southern California in the form of frozen fillets, sticks, and portions. Finally, the authors emphasize that price competitiveness is essential in processed fish products. In conclusion, the report states: "We believe that Alaska bottomfish may one day soon also be exploited in an economically profitable manner. Certainly the resource and the potential markets both exist."[2]

In a study perhaps most relevant to the current work Lea and Roy have examined the economic feasibility of

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[2]U.S. Department of Commerce, Area Redevelopment Administration. 1965. A Market Research Study for a Proposed Alaska Bottomfish Industry. Wolf Management Services, New York, pp. 80.

processing groundfish from the Gulf of Mexico [25]. The authors hypothesize that lack of economic information serves to impair development of this industry. This work is broken down into three phases. The first phase looks at whether supplies of groundfish are sufficient to support processing facilities. Both survey and catch data are used to demonstrate that there exist adequate biological supplies to sustain a processing plant. A survey among fishermen was then conducted to determine the ex-vessel prices for groundfish necessary to represent sufficient economic incentive to land these species. It is hypothesized that at any ex-vessel price of \$.03-\$.06/pound, a processing plant could expect to receive sufficient quantities of groundfish to sustain operations.

The second phase of the work focuses on selection of those groundfish products which have the greatest economic potential. The four product forms receiving most attention are: headed and gutted, blocks, IQF fillets, and minced fish.

A detailed description of the technological requirements of a plant precedes phase three of the study, determination of the optimal product mix. Linear programming is used in the optimal product mix analysis, with estimated margins at each stage of production providing the economic information.

The economic feasibility analysis is then conducted for three plant sizes. Three measures of profitability are employed, return on investment (ROI), internal rate of return (IRR), and the payback period (PP). The larger plant size generates the largest percentage return for all three criteria. The authors indicate that the calculations are based on preliminary information, and that the model should be altered as time permits to include more recent data.

Although commonly employed by businessmen, the payback period and return on investment criteria are insufficient from an economist's standpoint. The main criticism stems from the failure to consider that a dollar today is worth more than a dollar at some point in the future. Aside from this facet of the study, the general framework is quite applicable in addressing the problem of pollock processing feasibility.

III. UNCERTAINTY AND THE PROCESSING SECTOR

This chapter introduces some of the uncertainties with which a potential pollock processor must deal in his decision-making processes. A general discussion of uncertainty in economic decision-making is provided to acquaint the reader with the basic issues in this area. This is followed by a discussion of the supply variability problem. Finally, several other sources of uncertainty are discussed.

Decision-Making Under Uncertainty

Traditional microeconomic theory is based upon the assumption that the markets in which the economic agents act are perfectly competitive. One of the requirements of a perfectly competitive market is that the decision-makers have perfect knowledge of all conditions affecting their economic behavior. This assumption of perfect knowledge has received considerable attention by economists during this century, and a branch of theory examining economic behavior under conditions of imperfect knowledge has evolved. A distinction was made between risk and uncertainty by Frank Knight [24] in 1921. Knight considered risk to be those uncertainties which can be reduced to objective, quantitatively determined probabilities, and hence can be measured. Knight referred to uncertainty as those instances for which probabilities cannot be determined, and hence are unmeasurable.

Knight's distinction between risk and uncertainty is probably less helpful to the researcher than more recent writings on the issue. As pointed out by Walker and Nelson [43], Knight's classifications represent the two extremes on a continuum of imperfect knowledge. Recognition of the existence of subjective probabilities is a key facet of more recent thinking. A more explicit breakdown of the possible outcomes resulting from a decision is provided by Cohen and Cyert [14]. They make the following classifications:

1) Certainty
2) Objective Risk: possible to compute probability
3) Subjective Risk: decision-maker has no objective basis, but feels he knows the probabilities
4) Uncertainty: not possible to formulate probabilities

Subjective probabilities, sometimes called judgmental probabilities, are usually defined to be the degree of belief or strength of conviction an\individual has that a particular state will occur. These subjective probabilities are based on the person's past experience and knowledge of previous objective evidence. There are several methods currently used in decision analysis to extract these probabilities. One of the simplest is used in this research, the triangular density function. This and other methods (such as mathematical programming) comprise but a part of the expanding field of decision analysis under uncertainty.

Causes of Uncertainty in Pollock Processing

Variability of Supply

Any seafood processing operation which depends upon direct vessel delivery to its receiving facilities for a supply of fish experiences an element of uncertainty in its operations. This uncertainty may arise from one or a combination of the following factors affecting supply: (1) the resource itself, (2) weather, (3) the harvesting capacity, and (4) the difference between the fishermen's and processor's economic incentives.

The pollock resource in S.E. Alaska will be discussed elsewhere in some detail. However, a few characteristics of fish populations will be noted here in the context of supply variability. First, natural fluctuations in abundance are unavoidable in any biological population. Secondly, particularly in the case of a newly exploited resource, gaps in knowledge will inevitably exist. In the case of pollock in S.E. Alaska, the distribution of the resource during the various seasons of the year is not currently known with any degree of confidence. Third, the seasonal movements (to different depths) of pollock are not fully understood, necessitating some degree of experimental fishing at the inception of the fishery.

Weather can play a significant role in the availability of supply to a seafood processor. This is due to the fact that the relatively small trawlers in use by West Coast fishermen cannot fish effectively in extremely rough seas. If a winter storm should continue for a week or so, disallowing fishing for pollock, the processor would not receive a supply of raw product to the plant. Although a summer fishery is a possibility, given the existing trawl fleet and alternative summer fisheries it appears as though a winter/spring pollock fishery is more likely to develop.

The existing trawl fleet in S.E. Alaska is presently quite limited, and a potential pollock processor must consider this limited harvesting capacity as a source of uncertainty. The uncertainty arises due to two characteristics of the fleet. First, of the existing vessels trawling in S.E. Alaska, very few of them have the capacity to trawl in mid-water. Conversations with trawl fishermen and NMFS gear development specialists reveal that the most efficient method of harvesting pollock is otter trawling in mid-water. This technique requires that the vessel possess a minimum amount of horsepower in order to capture the fish (500 h.p. is often cited as the minimum). The existing trawl fleet with permits for bottomfish indicating S.E. Alaska residences is listed in Table 1.

Table 1. Vessel descriptions of bottomfish permit holders with Southeast Alaska home addresses, as of October, 1977. (Source: NMFS, Juneau, personal communication).

	Vessel Descriptions	
Gear Type	Tons	Length
Beam Trawl	5	25 ft.
Beam Trawl	?	30 ft.
Otter Trawl	36	60 ft.
Otter Trawl	?	?
Otter Trawl	45	49 ft.
Otter Trawl	8	28 ft.

As can be observed in Table 1, there are currently six vessels licensed to fish bottomfish in Southeast Alaska. The ISI plant at Petersburg is currently receiving its pollock from two vessels: the Kimber, a converted limit seiner, and the Kupreanof a cannery-owned trawler/tender. Of these two vessels, only the Kupreanof has the potential capability of trawling in mid-water. It should be noted, however, that there are other vessels in S.E. Alaska not currently licensed to fish bottomfish which could enter the pollock fishery. There also exist alternative fishing techniques (purse seining, Danish seining, and gillnetting) to trawling, which may prove effective for harvesting pollock in certain locations where trawling is not feasible.

The second characteristic of the fleet which may give rise to uncertainty is the limited number of vessels delivering pollock to the ISI plant. With only two trawlers delivering nearly all the pollock, supply can be drastically reduced should one vessel cease fishing due to a mechanical breakdown or a decision by the skipper to deploy the vessel elsewhere.

The fourth factor accounting for possible variability in supply is the divergence in economic incentives between the harvesters and the processors. This divergence may arise due to the different opportunity costs of the resources employed in pollock production. Opportunity costs are defined by Ferguson and Gould as: "The alternative or opportunity cost of producing one unit of commodity X is the amount of commodity Y that must be sacrificed in order to use resources to produce X rather than Y" [15, pg. 181].

Stated differently, for the fisherman the opportunity cost of resources used in pollock production is the foregone production in other fisheries. For the processor, the opportunity cost of resources used in processing pollock is the foregone production of other seafood products. Due to the fact that production and marketing relationships differ for processors and harvesters, the opportunity costs of producing pollock may be very high for the fisherman and low for the processor. This situation could create discontinuities in the production of pollock by a processor.

Subjective Probabilities. Some of the salient reasons why a pollock processor cannot count on a stable stream of supply have been explicated above. Uncertainty with regard to supply is the single most critical factor affecting development of a pollock fishery in Southeast Alaska. Supply uncertainty is therefore the focal point of this work. In order to evaluate economic feasibility, some range of expected production must be selected for the 10 year investment horizon used in this analysis.[3] In order to avoid arbitrary selection of production volumes, it was decided that a probability distribution considering a range of possible volumes would be preferable. As pointed out by Cassidy, *et al*. [11], when evaluating investment proposals influenced by stochastic events, subjective probabilities must be used to generate the probability distribution. These subjective probabilities are often implicitly used by decision-makers; it would seem desirable then to include them explicitly in the model.

The Triangular Distribution. The task is to elicit the subjective probabilities of the projected levels of pollock production at the ISI plant over the next 10 years. The triangular distribution is one of the more straightforward methods of estimating these subjective probabilities. The triangular distribution is attractive because it can be uniquely specified by three parameters and easily understood by the managers who estimate the parameters. The managers or other knowledgeable persons need only estimate: (1) the minimum volume expected in each of 10 years, (2) the most likely volume, and (3) the maximum volume. From these three values, the probability distribution for the

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[3] Ten years is assumed to be the useful life of the processing machinery, with a 10% salvage value at the end of the ten-year period.

volume of pollock production at the ISI plant can be derived for each of the ensuing 10 years. The mechanics of the triangular distribution and the techniques used in this analysis will be detailed later. The purpose of introducing the approach here is to underscore the importance that variability of supply and the resulting uncertainty regarding future volumes of production assume in examining the question of economic feasibility.

This inability to guarantee a stable source of supply has also hampered previous attempts to develop hake (*Merluccius productus*) resources off the Pacific Coast. As reported by Nelson and Dyer [27], a plant was established at Aberdeen, Washington in the mid-1960's to produce meal and oil from hake. The supply of fish to the plant at Aberdeen was a continual problem. In 1977, Tom Lazio Fish Co. in Eureka, California began production of hake fillets. Again, the processing plant experienced an erratic supply of hake, making production planning difficult.

Stabilizing Supply. A seafood processor recognizing the potential variability in the supply of pollock may choose to adopt one of several strategies to attempt to stabilize supply. The traditional supply relationship consists of fishermen-owned vessels selling fish to the processor in the absence of any long-term price or quantity commitments. Under this arrangement the processor has very little control over the timing and quantities of fish delivered to the plant. As a consequence, discontinuities in the quantity of fish supplied often occur.

A common institution in the fishing industry today is for the processor to provide non-price concessions to fishermen. The provision of ice, bait, shore facilities (showers, etc.), and unloading preference are examples of such concessions. These concessions are usually understood as a per fisherman cost-subsidy, rather than a per unit subsidy. The purpose of these concessions is largely to insure that a certain cadre of fishermen consistently deliver to a particular processor. In essence, then, non-price concessions may serve to stabilize the number of fishermen delivering to a plant, and indirectly to stabilize the quantity of raw product received.

Contractual agreements may also be employed by the processor in an attempt to stabilize supply. A cost-plus agreement effectively shifts the risk of fishing from the fisherman to the processor. An agreed upon premium over and above the costs of fishing is paid the fisherman at the conclusion of each trip or at the end of the season. This arrangement can only be effective, though, if the contract specifies how a least-cost performance on the part of the fisherman is to be insured.

Another possible contractual arrangement is an agreement similar to that employed by some fisheries cooperatives. Prior to the season a set price per pound is agreed upon which is paid to the fisherman for deliveries throughout the season. At the end of the season an additional payment is made to the fisherman based on the price movements for the species during the season.

Finally, an arrangement fairly common in the Oregon groundfish industry qualifies as a type of contract. A processor agrees to purchase species X in return for being supplied species Y. This may be the only effective way of obtaining sufficient quantities of Y, for which there may be significant cost or revenue advantages in processing.

Another method processors may employ to stabilize deliveries of raw product is to enter into partnerships with the vessel owners. A partnership can be understood here to mean a legal relationship whereby the parties agree to share the costs and returns of an operation. Under a partnership, the risks of fishing as well as the risks of holding inventories are shared between fishermen and processors.

A type of partnership in which the processor bears part of the risks of fishing is referred to as the "coinsurance" principle by Bhongsvej and Smith [6]. In this plan the fisherman agrees to supply fish continuously to the processor. The processor pays the operating expenses of the vessel throughout the season. When the products are sold, processing costs and fishing costs are deducted from revenues generated. The remaining profits are then shared according to a predetermined formula.

The above contractual arrangements and partnerships may indeed stabilize supply to the processing plant. However, these agreements may also entail some increased costs in the form of higher ex-vessel prices paid to the fishermen. These increased costs may be more than offset, though, by the advantages the processor may gain due to insuring a stable flow of raw product. It should be noted, however, that these advantages can only be obtained if conflicts over fishing vessel operations between fishermen and processors can be avoided.

The final arrangement whereby a processor may attempt to stabilize supply is through outright ownership of fishing vessels. Greig [16] enumerates some of the possible advantages of vertical integration. The first is as a protection against uncertainty. Vertical integration can assure the flow of raw product to the plant and keep operating costs at a minimum. Secondly, management can be improved through increased control over production. And, thirdly, economies of scale can be realized, as the most efficient scale for one stage of production can be matched with the most efficient scale for the subsequent stage.

This list of possible fishermen-processor arrangements is by no means fully exhaustive. It represents an attempt to examine some of the possible alternatives by which a pollock processor may attempt to insure a more even flow of raw product to the plant. Trawl fishermen in Petersburg and managers at ISI were both asked to evaluate the above arrangements. The response was nearly identical in that both groups favored the traditional situation where fishing operations are kept independent of processing operations. The fishermen reacted strongly against the prospect of competing with processor-owned vessels, which they claim could be subsidized, and thus sell at below cost. The ISI management indicated that they "are not in the fishing business," and that the processing firm is sensitive to local outcry against processor-owned vessels entering the fishery.

It is interesting to note, however, that of the two vessels currently delivering pollock to the ISI plant, one of them is owned by ISI. Apparently, during at least the initial stages of a pollock fishery, processors can be expected to enter the harvesting sector. There are economic advantages to the processor of vertically integrating into the harvesting sector. These advantages stem from the efficiency gains realized by management being able to control decision-making in the two subsequent stages of production. In addition, the costs associated with the negotiation of ex-vessel prices are eliminated. Both of these factors, the efficiency gains and the elimination of transactions costs, serve to reduce some of the uncertainty arising from supply variability.

Supply variability is an acute problem particularly during the initial two or three years of a new fishery's development. As fishermen acquire more experience with new types of gear and learn where the pollock are distributed throughout the year, catches can be expected to stabilize somewhat. This experience more than any other factor is probably going to resolve a substantial portion of the supply variability problem in the ensuing years of the fishery.

New Technology

An additional source of uncertainty for the pollock processor is the mechanical processing equipment used in the production of pollock fillets. Machine heading and gutting, filleting, and skinning of fish is a technology fairly new to Alaskan seafood processors. Most of the machinery comes from Europe, and only experimentation will document its effectiveness in handling Alaska pollock. The most efficient design of a processing line, the amount of adjustment required on the machinery, and the degree of maintenance required are all unknown at the outset of pollock production.

Pollock Markets/Prices

The markets for seafood products are always a potential source of uncertainty for a processing firm. Pollock markets in particular are treated elsewhere in this work. In the context of uncertainty, though, it should be noted that world-wide fluctuations in landings of seafoods precipitate continually changing market relationships for pollock products.

Institutional Policies

The Fisheries Conservation and Management Act of 1976 (FCMA) established regional management councils with the authority to manage fisheries from 3-200 miles offshore. The North Pacific Fisheries Management Council (NPFMC) has jurisdiction over fisheries within waters off the Alaska coast. The NPFMC is an entirely new management body, under the purview of the Secretary of Commerce, whose policy decisions vitally affect the course of Alaskan fisheries, both domestic and international. A pollock processor must be cognizant of the workings of this powerful body. Two issues are of especial significance to a pollock processor. The first is the respective allocations of pollock between domestic and foreign fishermen. This of course is relevant to the extent that a processor will receive pollock caught outside three miles. Of even greater import is the decision by the NPFMC whether or not to allow joint-ventures to operate in Alaska. Currently there are two proposals for a Korean-owned processing ship to anchor inside 3-miles and receive pollock from U.S. trawl fishermen. One of these proposals is for S.E. Alaskan waters, and the management at ISI claims that if approved, it would effectively put them out of the pollock processing business. The fishermen are not anxious to sell to the foreigners, though, and there is some question as to which U.S. fishermen would deliver the pollock. However, at this writing the issue has not been resolved, and the domestic pollock processor must view this as a considerable source of uncertainty. A decision by the NPFMC on whether or not to allow the joint-ventures will be made in July, 1978.

The Southeast Alaska pollock fishery is currently developing on stocks of fish caught within three miles. The management jurisdiction for this fishery lies with the Alaska Department of Fish and Game. Again, being a new fishery, there is no management precedent upon which the processor can base his expectations as to upcoming regulations.

The final institutional policy mentioned here as a potential source of uncertainty is the degree and form of government involvement in fisheries development. The state of Alaska has implemented a loss-guarantee program, through which two processors who indicated an intention to enter groundfish processing (ISI was one), were granted $145,000.00 each to allay production losses should they occur. The possibility of further state action to stimulate groundfish development still exists. The U.S.

Department of Commerce is currently seeking to distribute excess revenues from fisheries tariffs and foreign license fees to development projects. It is likely that some joint industry-government sponsored production trial fishing for Alaska groundfish will materialize in 1978.

These institutional policies, when added to the list of other uncertainties . . . the resource, new technology, and pollock markets, create a formidable obstacle to development of a pollock fishery. This is not to say that a pollock processing sector in Southeast Alaska will not develop, but that the entrepreneur must make some intrepid projections. Some information on the processing economics is provided in the following chapters to facilitate the entrepreneur's decision making.

IV. METHODOLOGY

Four components of fisheries development are illustrated in Figure 1. Resource availability, harvesting capability, and the marketing and distribution framework are not investigated as extensively as the processing sector, and are treated in a more descriptive manner.

A general statement is made as to the ability of the pollock resource in S.E. Alaska to sustain commercial harvesting and processing operations.

An economic analysis of harvesting feasibility is not undertaken in this work. The reason is essentially twofold: (1) the fishermen are not the recipients of state funds as is ISI, and are not bound by contract to reveal their costs, and (2) because of the very finite size of the fleet (two vessels), publication of production costs would disclose the operations of individual vessels. Current ex-vessel prices for pollock are used as the basis for the minimum cost assumptions in the processing feasibility analysis. A range of ex-vessel prices higher than the current prices are used for the alternate cost assumptions also evaluated.

Information on existing markets for pollock products is obtained from secondary sources. Due to the uncertainties currently surrounding potential foreign markets,

RESOURCE AVAILABILITY

: biological status of stock
: optimum yield
: previous harvest levels
: seasonal distribution
: government regulations

↓

HARVESTING CAPABILITY

: gear/techniques
: ex-vessel prices
: fleet capacity

↓

PROCESSING CAPACITY

: technology
: production costs
: product forms

↓

MARKETING/DISTRIBUTION

: wholesale prices
: U.S. markets
: export markets

Figure 1. Factors to be considered in development of a domestic pollock fishery.

emphasis is placed upon the status of the U.S. market. National Marine Fisheries Service (NMFS) data are utilized to examine recent price trends for pollock blocks. Additionally, some observations on the demand for groundfish products are made based upon recent empirical work done at the University of Rhode Island. Because of the size specificity of the filleting machinery, both (1) headed and gutted and (2) filleted pollock must be produced, since all pollock received are not the proper size for filleting. The price for headed and gutted pollock is treated as constant in this research, @ 17¢/lb., f.o.b. Petersburg. At the present time, the market for headed and gutted pollock is quite small compared to the market for pollock blocks. The price of pollock blocks is taken to be of primary interest, and determined endogenously in this work.

Processing Feasibility

As stated above, the objective of this work is to evaluate the economic feasibility of pollock processing in Southeast Alaska. The approach taken is to evaluate the decision to invest in the capital equipment required for pollock production in a manner consistent with accepted investment analysis procedures.

Before proceeding with a discussion of various techniques of investment analysis, an assumption implicit within most techniques will be made explicit. The assumption is that decision-makers in a seafood firm seek to maximize the net worth to the owners. It is recognized that in actuality a manager may have several objectives, but that maximizing net worth is taken to be the most relevant to analyzing an investment proposal.

A partial-budgeting framework is utilized to assess the effects on costs and revenues of establishing a pollock processing line. It is assumed that only firms currently engaged in seafood processing with plants in existence will consider initiation of pollock processing. Since only part of the business will be affected by pollock operations, the partial-budget was judged appropriate. As stated by Smith [33], three principles warrant consideration when using a partial-budget. First, only those costs and returns that will change if the action is taken should be included in the budget. Second, non-monetary factors need to be considered after the budget is completed. Third, it is important to know how accurate the partial-budget is.

Measures of Investment Worth

Much of the following material has been drawn from two main sources, The Capital Budgeting Decision, by Bierman and Smidt [7], and Capital Investment Analysis, by Aplin, Casler, and Francis [3].

Capital investment decisions are very important as they influence the long-run flexibility of the firm. Therefore, it is critical that a valid measure of investment worth be employed by managers in their decision-making. One measure of investment worth frequently used by businessmen is known as the payback period. Very simply, the payback period is the time it takes to repay the initial investment. The shorter the payback period, the higher the ranking of the investment. This can be written as:

$$P = \frac{C}{E}$$

where: P = payback period, in years

C = capital required

E = additional average annual after-tax earnings, before depreciation, expected from investment

The payback period is an insufficient measure because: (1) it ignores the entire economic life of the investment, (2) it fails to take into account the timing of proceeds earned prior to the payback date, and (3) it is more a measure of liquidity than of profitability.

Another measure of investment worth commonly used is the return on investment (ROI). This can be expressed as:

$$R = \frac{E - D}{C}$$

where: R = average annual rate of return

E = expected annual after-tax earnings, before depreciation, from investment

D = additional average annual depreciation

C = amount of capital required at time of investment

Although ROI does consider the entire economic life of an investment, it also contains some pertinent shortcomings. The R computed is not comparable to figures on bonds, interest or borrowed funds, etc., since such rates are computed on capital in use from year to year rather than on the average investment. Also, the ROI method fails to take into account the timing of cash outlays and benefits.

The above two measures of investment worth were deemed insufficient primarily because they fail to consider the time value of money. The time value of money is comprised of three components: alternate uses for the money, a risk premium, and an inflation premium. Measures of investment worth which do take into account the time value of money are called discounted cash flow measures. Two such measures are the internal rate of return (IRR) and net present value (NPV).

The IRR method involves finding a discount rate which makes the present value of cash inflows just equal to the present value of cash outlays for an investment. Expressed as a formula, the IRR is:

$$C = \frac{A_1}{(1+r)} + \frac{A_2}{(1+r)^2} + \ldots \frac{A_n}{(1+r)^n} + \frac{S}{(1+r)^n}$$

where: C = capital expenditure required

$A_1, A_2 \ldots A_n$ = cash inflow after taxes in years 1,2,...n

r = rate of return that will equate the income stream to capital outlay required

n = expected economic life of the project

S = estimated salvage value in year n

The r or internal rate of return represents the highest rate of interest an investor can afford to pay on borrowed funds. The decision rule is stated as follows: if the IRR is greater than the investor's minimum acceptable rate of return, the investment is justifiable.

The NPV method involves four discrete steps. First, an appropriate rate of discount is selected which reflects the minimum allowable rate of return. Then the present value of net cash inflows is computed. Third, the present value of net outlays is computed. And fourth, the outlays are subtracted from the inflows to yield the net present value. This process is expressed as:

$$NPV = PVR - PVC$$

$$PVR = \frac{R_1}{(1+r)} + \frac{R_2}{(1+r)^2} + \ldots \frac{R_n}{(1+r)^n} + \frac{S}{(1+r)^n}$$

$$PVC = C_I$$

where: NPV = net present value

PVR = present value of net revenues

PVC = present value of costs

$R_1, R_2, \ldots R_n$ = net cash inflows after taxes in years 1,2,...n (revenues net of operating and maintenance costs)

r = rate of discount

n = expected life of the asset

S = salvage value of asset in year n

C_I = initial capital expenditure

The decision rule using NPV is very simple. If NPV is greater than zero, the investment is economically viable. If NPV is less than zero, the investment should not be made.

It was stated earlier that both the IRR and NPV are valid measures of investment worth. It should also be mentioned that in most cases the two criteria will lead to the same decision. However, under certain circumstances the IRR method can lead to incorrect decisions. This can occur when evaluating mutually exclusive investments or when evaluating investments which involve more than one period of cash outlays interspersed with cash inflows. In addition, the NPV method is generally simpler to compute. The feasibility of pollock processing will therefore be evaluated using the net present value method.

The particular application of the NPV technique in this research entails some explicit assumptions. First, the decision was made to use pre-tax cash flows rather than after-tax flows. This has been done primarily since a partial-budgeting approach has been taken. The revenues generated from pollock processing are likely to comprise but a minor portion of total firm revenues. Since taxes are assessed on the total revenues of the firm, it would be difficult to determine what marginal tax rate should apply to the pollock processing operations. Thus all cash flows have been computed on a pre-tax basis. Secondly, current-year (constant) prices are used over the ten-year investment horizon because current-year costs are also used for the same period. A range of costs is utilized which is then treated as constant over the ten years. This is recognized as a limitation of the analysis, but deemed a necessary measure in the absence of reliable price forecasts for pollock blocks. Finally, a range of discount rates, $r = 0.10$, $r = 0.15$, and $r = 0.20$, is used to allow the reader to choose the minimum acceptable rate of return.

The Triangular Distribution

The NPV technique requires estimates of future volumes as well as prices in order to generate revenue streams over the life of the investment. As noted earlier, estimates of future volumes of pollock production are extremely hazardous due to the supply variability problem. For this reason it was decided to use a probability distribution of volumes rather than a single estimate. When an investment proposal is influenced by random events, subjective probabilities are required to estimate the distribution of outcomes [11].

The triangular distribution function is used to estimate these subjective probabilities in this work. This distribution has been used successfully to evaluate research expenditures by Sprow [34], to look at investment decisions under uncertainty, by Swirles and Lusztig [35], and by Cassidy, et al. [11] to estimate the effects of pasture improvement investments.

Following Cassidy, et al., [11], the probability density function of the triangular distribution is:

$$f(x) = \frac{2(x-a)}{(c-a)(b-a)}, \quad a \leq x \leq b \tag{1}$$

$$f(x) = \frac{2(x-c)}{(c-a)(b-c)}, \quad b \leq x \leq c \tag{2}$$

where: x = the value of a particular variable

a = the estimated minimum value of x

b = the estimated "most likely" value of x

c = the estimated maximum value of x

f(x) = probability density function

Some desirable properties of the triangular distribution are: (1) the triangular distribution is completely specified by three parameters, a, b, and c; (2) the parameters of the triangular distribution are more easily understood by decision-makers than probability assignments; and (3) the distribution is capable of being skewed. In this research, estimates of the minimum, most likely, and maximum volumes are obtained for each year over the ten year investment horizon, providing a different triangular distribution for each of the ten years. Estimates of these volume levels were obtained from two sources and averaged. One set of estimates was obtained from personnel at ISI and the other from the ADF&G area management biologist. These estimates are listed in Appendix Table A.

The triangular density function is represented graphically in Figure 2.

In order to get the cumulative probability function, $F(x)$, we integrate the triangular density function: $F(x) = \int f(x)dx$ such that $F(a) = 0$ and $F(c) = 1$. This gives us:

$$F(x) = \frac{(x-a)^2}{(c-a)(b-a)}, \quad a \leq x \leq b \tag{3}$$

$$F(x) = 1 - \frac{(x-c)^2}{(c-a)(c-b)}, \quad b \leq x \leq c \tag{4}$$

The cumulative probability function is illustrated in Figure 3. Next we solve for x in terms of $F(x)$:

$$x = a + [F(x)(c-a)(b-a)]^{\frac{1}{2}}, \qquad a \leq x \leq b \tag{5}$$

$$x = c - [(1 - F(x)(c-a)(c-b)]^{\frac{1}{2}}, \quad b \leq x \leq c \tag{6}$$

By random selection of the ordinate, $F(x)$, we can then derive a value of x, the variable subject to stochastic variation (volume in this case). $F(x)$ is interpreted to

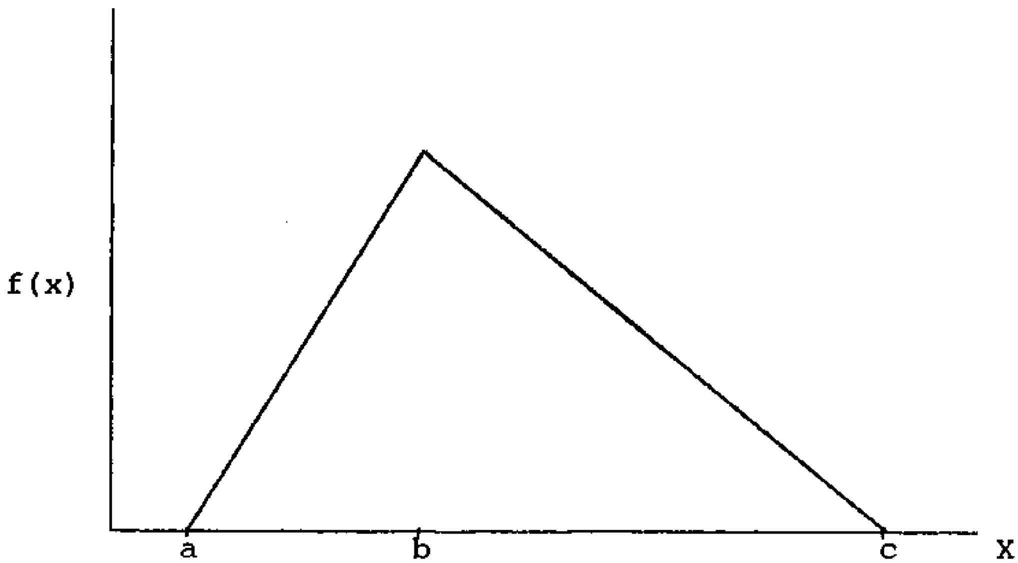

Figure 2. The triangular density function.

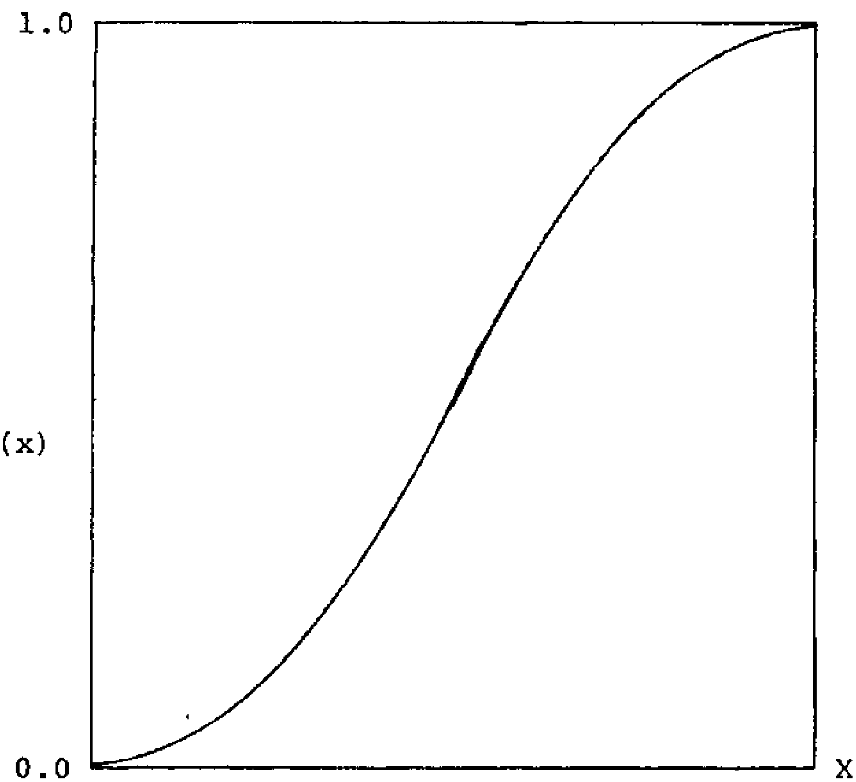

Figure 3. The cumulative probability function for a triangular distribution.

mean the probability of a volume being less than or equal to some specified value of x.

Monte Carlo Simulation

The second stage of the technique is to randomly select a sufficient number of F(x) values to generate a cumulative probability function of volumes for each of the ten years. A Monte Carlo random number program is used to generate 95[4] values of F(x) for each of the ten years. For example, a value of F(x), say 0.41, is randomly selected, substituted into the appropriate equation[5], (5) or (6), with the parameters a, b, and c for that year, yielding a level of volume, x*. The interpretation is that the probability of attaining a level of volume $\leq x^*$ is 0.41. This procedure is repeated 95 times for each year, generating a probability distribution of volumes for each of years one through ten. For purposes of the calculations below, these volume distributions can be described by an

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[4]Originally 150 values of F(x) were randomly selected by the Monte Carlo simulation, generating a distribution of 150 volumes per each year, and ultimately a distribution of 150 break even block prices for each set of assumptions. However, computer storage limitations restricted the number of observations to 95 on each variable. Due to the fact that all of the distributions of block prices exhibit very little variation, it was decided that 95 observations is a sufficient number for the purposes of this research.

[5]The value of $F(b) = \frac{(c-a)}{(b-a)}$. If $F(x) \leq F(b)$, equation (5) is used, and if $F(x) \geq F(b)$, equation (6) is used.

[n x t] random volume matrix of the following form:

$$
\begin{matrix}
V_{11} & \cdots & V_{1t} \\
\vdots & & \vdots \\
V_{n1} & \cdots & V_{nt}
\end{matrix}
$$

where: $n = 95$

$t = 10$

One Monte Carlo trial can be thought of as generating one row in the above matrix.

Determination of Revenue Streams

Having generated volume distributions in the above manner, cash flow estimates are then required for the NPV calculations. ISI personnel indicate that approximately 70% of the pollock received are a suitable size for filleting, while the remaining 30% must go into headed and gutted product. Since both products must be produced, it was decided that a weighted margin per pound of raw product would be used to calculate revenue from production. All variable costs of production, for both product forms, are listed in Appendix Tables C and D. These costs are all converted to ¢/lb. of raw product. In the same fashion, revenues from the sale of blocks as well as headed and gutted, are converted to ¢/lb. of raw product. These conversions allow calculation of:

$$\text{Net revenue/lb. of raw product} = 0.7(0.22(P_b) - VC_b) + 0.3(0.56(P_{hg}) - VC_{hg}) \quad (7)$$

where: 0.7 = proportion of raw product going into block production

0.22 = yield on blocks

P_b = wholesale price for frozen pollock blocks

VC_b = variable costs of producing blocks, in ¢/lb. raw product

0.3 = proportion of raw product going into headed and gutted production

0.56 = yield on headed and gutted product

P_{hg} = price for headed and gutted, fixed at 17¢/lb.

VC_{hg} = variable costs of producing headed and gutted product, in ¢/lb. raw product

The NR/pound is interpreted as the margin of sales revenues over the variable costs of production, converted to a per pound of raw product basis. If we label this NR/pound of raw product Y, then volume (V) times Y equals net cash inflows for a given cost assumption and level of P_b.

However, as was stated earlier, prices of pollock blocks, P_b, cannot be predicted with confidence over the next ten years within the limitations of this research. An attempt was made to specify an econometric model of block prices, but due to time constraints sufficient data on the independent variables could not be obtained. In order to predict future values for the dependent variable, block prices, one must project future values for each of the independent variables. Projections of world pollock landings, U.S. imports of pollock, and prices of substitutes, some of the independent variables considered, are not available at this writing.

The decision was made to solve the NPV equation for the break-even level of P_b. This is considered a more useful approach than either arbitrary selection of a range of prices or price forecasting in the absence of a tested model. In order to solve for the break-even P_b, initially the break-even level of Y must be established.

Mathematically, we have:

$$NPV = PVR - PVC$$

$$PVC = C_0 = \text{cost of investment in pollock processing facilities and equipment}$$

We are interested in the break-even NPV, or where NPV = 0. Thus we have:

$$0 = PVR - C_0$$

Substituting for PVR,

$$C_0 = \frac{V_{i1}(Y_i)}{(1+r)} + \frac{V_{i2}(Y_i)}{(1+r)^2} + \ldots \frac{V_{i10}(Y_i)}{(1+r)^{10}} + \frac{SV}{(1+r)^{10}} \qquad (8)$$

where: $V_{i1}, V_{i2}, \ldots V_{i10}$ = volume levels determined by Monte Carlo trials

i = 1,2,...n (number of Monte Carlo trials)

Y_i = Net Revenue/pound of raw product for the i^{th} trial

r = discount rate

SV = salvage value of machinery

Equation (8) can be rewritten as:

$$C_0 - \frac{SV}{(1+r)^{10}} = Y_i\left(\sum_{t=1}^{10} \frac{V_{it}}{(1+r)^t}\right)$$

Solving for Y_i:

$$Y_i = \frac{C_0 - \dfrac{SV}{(1+r)^{10}}}{\displaystyle\sum_{t=1}^{10} \frac{V_{it}}{(1+r)^t}} \tag{9}$$

for $i = 1, 2, \ldots 95$

Using the values from the random volume matrix, equation (9) gives us 95 values of Y, the Net Revenue/pound of raw product, for which the NPV of the investment equals zero, for a given discount rate. The next step is to convert this to a break-even level of P_b, the price of pollock blocks. Recalling equation (7), gives us:

$$\begin{aligned} Y &= 0.7(0.22(P_b) - VC_b) + 0.3(0.56(P_{hg}) - VC_{hg}) \\ Y &= 0.154(P_b) - 0.7(VC_b) + 2.856 - 0.3(VC_{hg}) \end{aligned} \tag{10}$$

since P_{hg} is fixed at 17¢/pound. For given levels of processing costs, VC_b and VC_{hg}, the frequency distribution of P_b can be determined using the values of Y_i from equation (9).

This in essence represents the output of the above model, the frequency distribution of pollock block prices, P_b, for which the NPV = 0, under a given set of assumptions. To evaluate economic feasibility, then, one chooses the level of cost assumption and discount rate deemed appropriate, solves for the break-even distribution of P_b, and compares this with the current market price for pollock blocks. If the current market price exceeds the break-even P_b, the investment is economically feasible under the chosen set of assumptions. If the current market price is less than the break-even P_b, the investment is not economically feasible.

One final variation in the analysis remains. Production costs and revenues vary depending on whether or not the pollock contain roe. When the fish contain roe, variable costs of production as well as revenues are different than under production without roe. Equation (10) represents the cost and revenue relationships for pollock production without roe. Appendix Tables E, F, and G provide the detailed breakdown of NR/lb. of raw product calculations for production without roe, production with roe, and mixed production. The analysis is undertaken for all three assumptions, with the emphasis on mixed production, ascertained to be the most realistic. It was assumed that 50% of yearly production will be with roe and 50% without roe, throughout the ten year period, for the mixed production analysis.

V. RESOURCE AVAILABILITY

The Pollock Resource in the Gulf of Alaska

The Gulf of Alaska is generally defined to include waters of the North Pacific between 170°W and 132°40'W longitude, or between the eastern Aleutian Islands and Dixon Entrance [28, p. 8]. Pollock now represents the largest exploitable biomass of gadoid (cod-like) fishes in the Gulf, due at least in part to the reduction in stocks of Pacific Ocean perch (*Sebastes alutus*) during recent years. Pollock, along with other groundfish species, occur mainly in waters of the continental shelf, at bottom depths between 30-200 fathoms. In summer pollock are thought to be most abundant between 50-150 fathoms, while in winter they move to 100-200 fathoms. Pollock mature at an average age of three years, have an average fecundity of 100,000 eggs, and spawn during the months March-June [28, p. 161].

During the past 25 years, groundfish surveys have been conducted in the Gulf by the National Marine Fisheries Service (NMFS), producing various types of biological information. These surveys are intended to provide unbiased estimates of the condition of groundfish stocks. Of perhaps greatest interest are the estimates of exploitable biomass, which are derived using the area-swept method. This method, as described by Alverson, *et al*. [1], assumes that the standard trawl captures all demersal fishes in its path. Average exploratory catch rates, average trawling speed, average working gape of the standard trawl, and area of the shelf covered are all considered in the estimation. The population (exploitable biomass) is calculated by multiplying the number of area units contained in a region by the yield in pounds/hour of trawling.

Maximum sustainable yield (MSY) can be derived from the estimate of exploitable biomass. MSY is defined as "the largest average catch which can be taken from a stock over a reasonable period of years under current environmental conditions" [28, p. 181]. For fish stocks near virgin conditions the Gulland [18] equation is appropriate for deriving MSY. This equation is

$$MSY = aMB_o$$

where a = constant = 0.4

M = instantaneous natural mortality rate

B_o = virgin biomass

Since pollock stocks in the Gulf have been fairly lightly fished, the Gulland equation is used to estimate MSY for pollock. The exploitable biomass was estimated to be 1.1-2.1 million mt for the Gulf [28, p. 186]. Assuming M to be 0.4, the estimate of MSY is between 169,000 and 338,000 mt for pollock in the entire Gulf of Alaska.

The Pollock Resource in Southeast Alaska

The Southeast Alaska statistical area is defined to comprise waters between Cape Spencer on the north and Dixon Entrance on the south. Because of the highly perishable nature of pollock, only fish caught within this region will be considered available to a fish processor located at Petersburg. The storage properties of pollock have been assessed in a joint industry-government venture on groundfish undertaken in 1974 [42]. Experiments were conducted to determine the effects of various storage mediums on the quality of fish flesh. Pollock which were well-iced remained in good condition for three days, after which time they began to deteriorate. Fish held in refrigerated sea water (RSW) at 30°F, were found to be acceptable up to a period of five days. Finally, pollock were held in slush-ice made by combining fresh water ice and salt-water and maintained at 31°F. These fish were found to be of equal appearance after seven days to those held in RSW for five days. The report concludes that pollock, which are chilled rapidly and maintained at a proper temperature, have a storage time of up to six days, and that a less than five day old fish is preferable. In order to insure a good quality catch, then, the fishermen can only range a limited distance (2-3 days) from the processing plant. For this reason the availability of the resource within

Southeast Alaska must be evaluated for purposes of the feasibility analysis.

Specific information on the status of the pollock resource in Southeast Alaska is less complete than for the Gulf as a whole. The research vessel John N. Cobb was utilized by NMFS to survey groundfish resources in Southeast Alaska during April-May 1976 [37]. The gear used in this survey was a standard 400-mesh Eastern bottom trawl. Throughout much of the survey area, the bottom was found to be very rough and not suitable for bottom trawling. The results indicate very low catch rates for pollock in outside waters. In inside waters, pollock catches were variable, with the highest concentration occurring in Sea Otter Sound. It should be emphasized though, that this cruise used only one type of net during just two months of the year.

During May of 1976, NMFS and local processors combined to charter the F/V Ocean Leader, to conduct further surveys for groundfish in Southeastern [38]. Two Norwegian fishermen were hired to demonstrate the use of several mid-water trawls. The outside waters from Cape Ommaney to Ice Bay were not found to contain significant concentrations of pollock. In inside waters, though, and particularly within Seymour Canal, the mid-water gear captured substantial quantities of pollock. In Seymour Canal pollock were found at 30-60 fathoms where the depth was 65-100 fathoms. In all, six mid-water trawls produced about 180,000 pounds of pollock from Seymour Canal.

Results from the 1977 research cruise in Southeast Alaska (John N. Cobb 77-3) are not available at this time. However, Steven Hughes, a fishery research biologist with the Resource Assessment and Conservation Engineering Division of NMFS, was contacted regarding the recent surveys.[6] Mr. Hughes expressed optimism when queried about pollock abundance in Southeast Alaska. In fact, the quantities of pollock appear to be increasing coincident with the demise of ocean perch stocks in the same area. Mr. Hughes noted that the early maturing, opportunistic feeding pollock have moved into the ecological niche once filled by the relatively late-maturing, low-fecund perch. Finally, Mr. Hughes noted that pollock in inside waters appear more pelagic than in outside waters, further substantiating the need for mid-water trawling capability.

In order to obtain an estimate of MSY for pollock in Southeastern Alaska, one must return to the Fishery Management Plan for the Gulf of Alaska Groundfish Fishery [28]. The exploitable biomass for the area is estimated to be 25,000-51,000 mt. Applying the Gulland equation yields an estimate of MSY for pollock in Southeast of 4,000 to 8,160 mt. This estimate, however, pertains only to those waters

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[6] Steven Hughes, personal interview, Seattle, Washington, October 17, 1977.

seaward of the Alexander Archipelago. Abundance estimates for the inside waters of Southeastern, where U.S. vessels are likely to operate, are not available at this time.

Pollock Exploitation in the Gulf

The large trawlers of foreign nations were the first to fish for pollock in the Gulf of Alaska. Vessels of the U.S.S.R. were the first to appear, deploying trawlers and support fleets in this area as early as 1962. The Soviets originally targeted on ocean perch, but this fishery peaked in 1965, forcing them to target on other species. As indicated in Table 2, Soviet catches of pollock have increased substantially in recent years.

Table 2. Approximate catches of pollock from the Gulf of Alaska, 1967-1976 (1,000 metric tons).

Country	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
U.S.	0	0	0	0	0	0	0	tr	tr	tr
U.S.S.R.	0	0	0	0	tr	20	29	31	38	40
Japan	6	6	18	9	9	14	7	30	10	14
R.O.K.	0	0	tr	0	0	1	1	0	0	6
Poland	0	0	0	0	0	0	tr	0	0	tr
TOTAL	6	6	18	9	9	35	38	61	48	60

Source: Fishery Management Plan and Environmental Impact Statement for the Gulf of Alaska Groundfish Fishery During 1978, N.P.F.M.C., Sept. 23, 1977, for years 1967-1975. "The Fisherman's News," May 1977, first issue, for 1976.

Japan began commercial trawling for groundfish in the Gulf in 1963. The Japanese employ primarily large factory stern trawlers in this area, although the Gulf fishery is much less extensive than the Japanese effort in the Bering Sea. The Japanese also originally targeted on perch, and have switched to other species in the last decade. The extent of Japanese pollock catches in the Gulf can also be obtained from Table 2.

Vessels of the Republic of Korea have been fishing in the Gulf since 1972, although catches of pollock have been quite modest. Poland began limited commercial trawling in the Gulf in 1974. To date the Polish have not harvested pollock in large quantities as seen from Table 2.

The catch data provided by foreign governments generally lack sufficient detail to permit allocation of harvests to specific areas within the Gulf. However, it is known that foreign catches did not occur with the inside waters of Southeast. To date, the harvest of pollock in S.E. Alaskan waters has been quite modest. In 1976 U.S. fishermen harvested approximately 186 mt of pollock from waters within Southeast Alaska, the majority of which was caught with purse seines [28, p. 73].

Based on the currently available information, a definitive statement of the potential yield from the pollock resource in Southeast Alaskan waters cannot be made. It should be re-emphasized that a processing plant in this region can expect to receive pollock from an area bounded by Cape Spencer on the north and Dixon Entrance on the south. It should also be noted that the existing trawl fleet in S.E. Alaska consists primarily of relatively small vessels converted to trawling from other fisheries. These vessels are restricted to fishing in inside waters by their size, in a region where no historical pollock exploitation has taken place.

Observations on Pollock Abundance in Southeast Alaska by U.S. Fishermen

Salmon fishermen in S.E. Alaska have noticed concentrations of pollock in Southeastern waters for many years. However, these sightings have nearly always been during the summer months when salmon fishing takes place. The assumption, perhaps unwarranted, was made that the pollock are present in large quantities during the winter months as well. The fact is that this assumption is based on conjecture rather than commercial fishing trials. Skipper Eric Grosvald of the F/V Kimber has been trawling during October, November and December of 1977, and as of yet has seen very little evidence of pollock. Although fishing with a bottom trawl, the side-scanning sonar has detected very little sign of fish in mid-water. Mr. Grosvald expressed that pollock may become more abundant during the months January-April.[7]

The Southeast Alaskan trawler's attitude toward the pollock resource can be summed up as follows. Basically, we need more information about the fish themselves: their feeding habits, diurnal movements, seasonal migrations, and spawning behavior. In addition, the fishermen need more experience fishing for pollock: with the electronics involved (sonar, net sounders, plotters, etc.), the mid-water nets which may be required, and with fishing during various months of the year.

Barry Bracken, Assistant Area Management Biologist for the Alaska Department of Fish and Game (ADF&G), also expressed that our current knowledge of the pollock resource is less than complete.[8] Mr. Bracken noted that the pollock do appear more abundantly in the summer months, and in fact may move offshore during the winter months. The commercial fishing season may not begin until January and last through April or May. Finally, Mr. Bracken confirmed that we do know that "krill," small shrimp-like euphausiids, serve as the primary food source of the pollock in Southeastern waters.

In summary, the current situation regarding the pollock resource can be characterized by a single word --

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[7] Eric Grosvald, personal interview, Petersburg, Alaska, December 20, 1977.

[8] Barry Bracken, personal interview, Petersburg, Alaska, December 21, 1977.

uncertain. Until more definitive information exists as to the availability of pollock throughout the year, no statement can be made as to the sufficiency of the resource to support a commercial fishery. In fact, at the current time, the availability of the resource during the winter months is the principal uncertainty clouding the issue of the economic feasibility of pollock processing in Southeast Alaska.

VI. POLLOCK MARKETS

U.S. Groundfish Consumption Trends

In 1976 the per capita consumption of fish and shellfish in the U.S. rose to 12.9 pounds, edible meat, equalling the record set in 1973. This is an increase of 0.7 pound over 1975, of which fresh and frozen finfish accounted for 0.5 pound of the increase [39].

Groundfish are generally consumed in the form of fillets, fish sticks, or fish portions. The major species consumed in the fillet form are cod, flatfish, ocean perch, and haddock. Since pollock are primarily consumed in the form of sticks and portions, emphasis will be placed on this product form in this exposition. Consumption of fish sticks and portions rose to a record 438.4 million pounds in 1976, an increase of 14% over 1975 (see Figure 4). This increase in consumption was stimulated by an expansion in sales by fast food restaurants. Approximately 75% of the portions marketed in the U.S. were sold to restaurants and institutions. Of the 438 million pounds of sticks and portions sold in 1976, 340 million pounds were in the form of portions [40].

This increased utilization of sticks and portions stimulated an increase in the importation of fish blocks, from which sticks and portions are made. Imports of fish

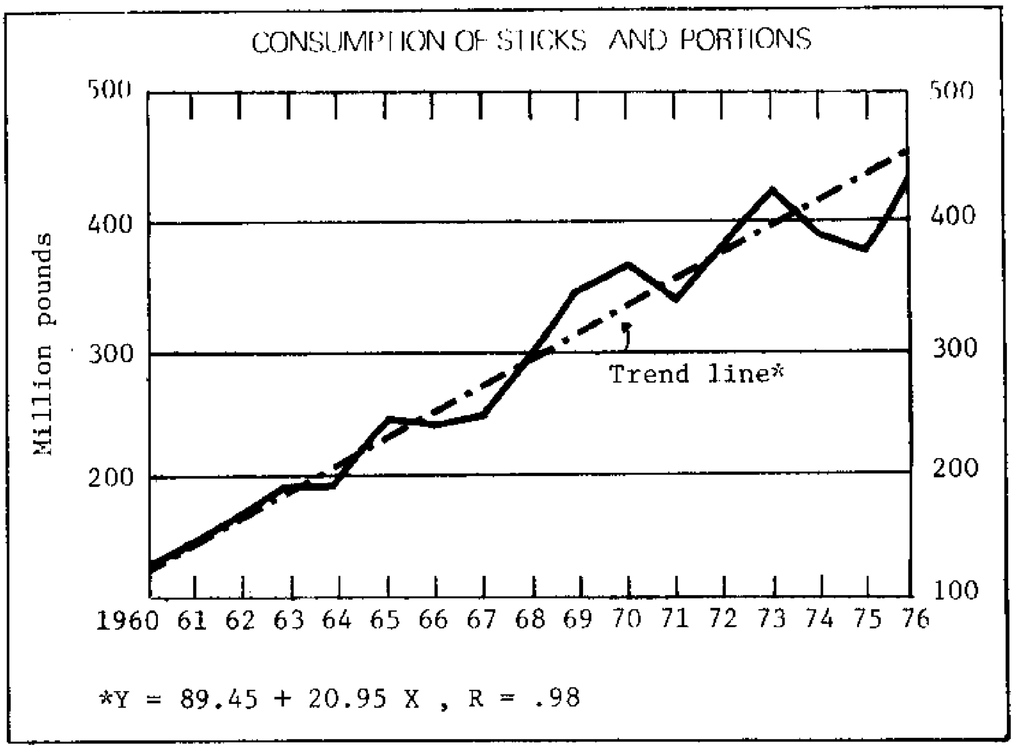

Figure 4. Consumption of sticks and portions, 1960-1976.
(Source: NOAA, NMFS, C.E.A. F-27)

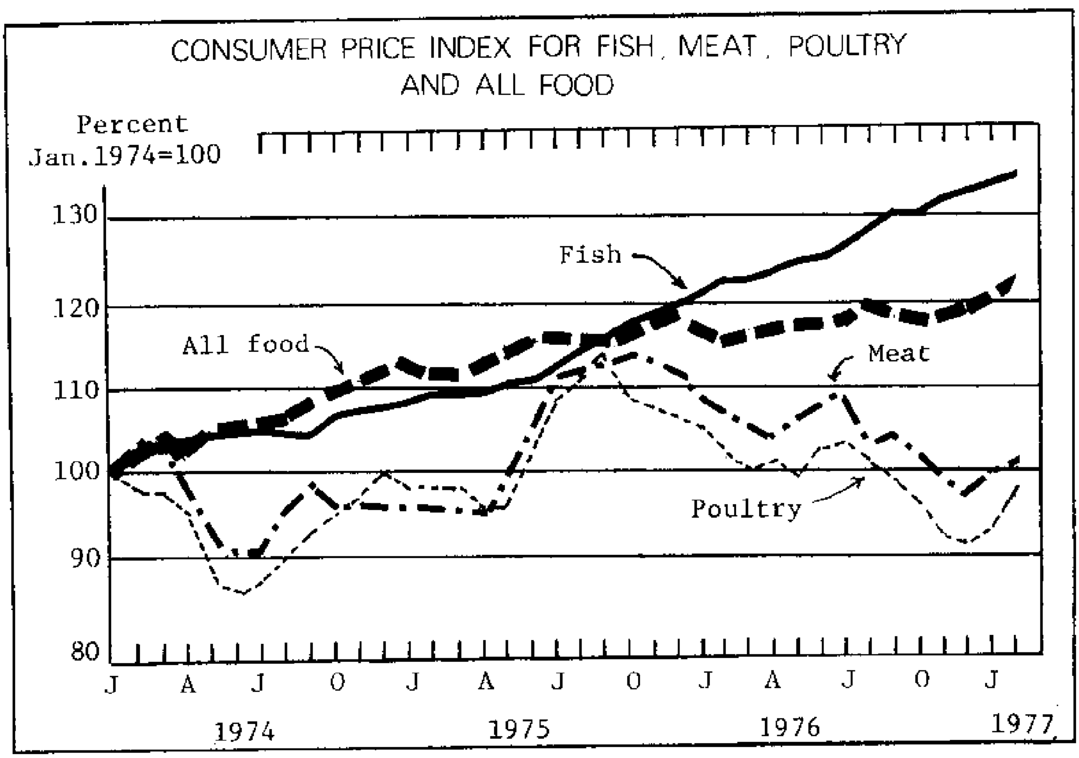

Figure 5. Consumer price indices, 1974-1977.
(Source: NOAA, NMFS, C.E.A. F-27)

blocks during 1976 reached a record 379 million pounds, an increase of 21% over 1975. Imports comprised 95% of all fish blocks utilized in the U.S. in 1976. The principal suppliers of blocks in rank order were Iceland, Republic of Korea, Canada, Denmark, Norway, and Japan [40].

Imports of pollock blocks, as seen in Table 3, totaled 95.7 million pounds in 1976. Korea supplied 61% of this

Table 3. U.S. imports of pollock blocks, by country of origin, 1974-1976 (product weight).

Country of Origin	1974	1975	1976
	(million pounds)		
Iceland	6.9	10.9	10.2
Republic of Korea	14.8	36.7	58.6
Canada	1.1	2.8	1.2
Denmark	5.3	3.1	5.0
Norway	1.6	3.8	5.1
Japan	47.0	15.5	10.5
Federal Republic of Germany	1/	0.1	1.9
Poland	-	0.2	2.0
United Kingdom	3.3	1.3	0.8
Other	0.1	0.4	0.4
TOTAL	80.1	74.8	95.7

1/ Less than 50,000 pounds.
Source: U.S. Department of Commerce, Bureau of the Census.

total followed by Japan with 11% of the total. During 1976, pollock block prices began at around 36 cents per pound, rose to 49 cents per pound in September, and remained steady throughout the remainder of the year (Table 4).

During the first half of 1977, the consumption of fish sticks and portions was 223 million pounds, virtually identical to that of the same period in 1976 [41]. The production of portions increased 1% to 176 million pounds, stimulated primarily by the fast food market, the principal outlet for portions. The wholesale prices of portions have risen appreciably during 1977, with cod portions reaching a record $1.14 per pound and pollock portions a record $0.78 per pound, both in September 1977 [41].

The wholesale prices of fish sticks also rose during the first three quarters of 1977. The price of cod sticks increased to $1.15 per pound in September, a gain of 17% over January. Pollock sticks rose to a price of $0.80 per pound, an increase of 18% over January [41]. Unlike portions, fish sticks are marketed primarily through retail stores, and rising prices of fish sticks may generate consumer resistance to continued buying. At the retail level, fish sticks compete with other protein sources such as meat and poultry. As indicated by Figure 5, the consumer price index for fish has risen at a faster rate than that of all food over the past two years. In addition, the price trend for meat and poultry since October of 1975 has been downward. Increased prices of fish sticks relative to other protein sources occurred at the same time as a 4% drop in production during the first half of 1977, compared with the same period in 1976.

Imports of fish blocks reached a record 190.9 million pounds during the first half of 1977. The utilization of pollock blocks rose to 50.6 million pounds during this period, an increase of 20% over 1976. Pollock blocks now comprise approximately one-quarter of the fish blocks imported and utilized in the U.S. Korea continued to be the major supplier of pollock blocks with 56% of the total, followed by Iceland with 14% and Japan with 12%. The wholesale price of Alaska pollock blocks increased 33% to $0.65 per pound in the January-June 1977 period, was quoted at a record $0.68 in September of 1977 and remained steady through December (Table 4).

U.S. Groundfish Demand: Functional Relationships

An econometric analysis of the demand for groundfish in the U.S. was recently completed by Bockstael [8]. This work is drawn upon here to help identify some of the functional relationships underlying the demand for groundfish products. Bockstael begins by questioning the conventional thinking that U.S. consumers will necessarily benefit from reduced foreign catches of groundfish resulting from quotas imposed by the FCMA. In fact, if these same foreign nations

Table 4. Wholesale prices of Alaska pollock frozen fish blocks, monthly, 1974-1977.

Month	1974	1975	1976	1977
January	52.8	31.0	35.6	49.0
February	51.8	31.8	36.0	48.6
March	50.3	34.5	37.5	49.5
April	48.5	34.5	38.4	1/
May	45.4	33.6	39.5	59.5
June	43.7	32.7	42.0	60.2
July	40.5	33.0	43.4	65.0
August	40.0	33.9	46.8	67.0
September	39.5	34.6	49.0	68.0
October	37.3	35.5	48.9	66.0
November	36.0	35.7	49.0	67.0
December	1/	36.2	49.0	68.0
Average	44.2	33.9	43.0	60.7

1/ Insufficient quotes.

Note: Prices to processors as quoted by producers, importers, and brokers at Boston, Gloucester, and New Bedford.

Source: Fishery Market News Reports, National Marine Fisheries Service, Boston, Massachusetts.

become competitors for groundfish previously exported to the U.S., prices may actually rise to U.S. consumers. By analyzing the demand for groundfish products, it is hoped that relationships such as the above can be clarified.

Bockstael examines the demand and supply relationships for U.S. groundfish imports. In the short run, landings of groundfish are not determined by price, but by capital stocks (vessels), weather conditions, and biological stocks of fish. This is not an uncommon phenomenon in the fisheries. The demand for a good is traditionally thought to be a function of the price of the good, the relative prices of substitutes, population, and income. The U.S. demand for groundfish imports is also strongly affected by tariffs on the groundfish products. One of the more important characteristics of the demand for groundfish imports is that it is an intermediary demand, not a final demand. The importers reprocess the fish blocks into sticks and portions and distribute the fillets through wholesale outlets.

Bockstael expresses the intermediary's demand for imports as: d = fn (import price, wholesale price, existing inventories, and several variables which reflect the desired level of inventories). The importer's prior contracts also significantly affect the demand for imports.

Of particular relevance to this work is Bockstael's conclusion that the demand for blocks doesn't seem to be significantly affected by relative prices. This can be explained by two phenomena: (1) intermediaries have no present alternative to imports, and (2) the trend in consumption of sticks and portions has been steadily upward over the past several years.

The supply of imports, however, does appear to be influenced by relative prices (U.S. import prices). Also significant in the supply equation were groundfish prices in West Germany, a large consuming nation, and world landings of groundfish.

Finally, Bockstael notes that the price elasticities of demand for groundfish products are extremely high. This means that a given percentage rise in groundfish product prices will result in a proportionately larger reduction in quantity demanded. Bockstael concludes that if foreign access to fish stocks is reduced due to quotas imposed by the U.S., resulting in a reduction in supply of groundfish products, then prices of groundfish products may not necessarily increase substantially. The reason is that the high price elasticities of demand indicate consumers would shift to other sources of protein as groundfish prices rise. Bockstael's conclusion seems reasonable when applied to the demand for fish sticks, which are marketed at the retail level. However, in 1976 93.4 million pounds of sticks were produced while portion production reached 340.1 million pounds [41]. There apparently is a separate demand for portions than for sticks, which may be less price elastic than the demand for sticks. This demand for portions, especially by fast food enterprises, may be sufficient to maintain fish block prices at their current record levels.

Foreign Markets

Extension of coastal nations' jurisdiction to 200 miles throughout the world has potentially significant implications for world groundfish markets. The distant water trawling fleets of many nations currently exporting groundfish products now face quotas in most of their traditionally fished waters. These countries' access to the resources has been curtailed markedly in some instances, thus creating the possibility that these nations may become net importers of groundfish products.

Korea, the major source of pollock imports to the U.S., has been virtually denied further access to pollock in waters of the U.S.S.R. ROK vessels formerly caught from 347,000 to 600,000 metric tons annually in these waters [28, pg. 92]. In addition, Korean vessels also face quotas in U.S. waters of the North Pacific.

Japan, the third largest source of pollock imports to the U.S., also faces severe quota limitations. Japanese vessels have previously harvested around 1,000,000 mt of pollock from U.S.S.R. waters; in 1977 their quota from these waters is 400,000 mt, a 60% reduction.[9]

Superficially, then, it would appear as though Japan and Korea are potential export markets for U.S. producers of pollock products. However, at this point in time the situation is clouded by import restrictions. Currently Korean law does not allow importation of pollock. Japan has a quota of 65,000 mt on imported round pollock. The possibility of Korean processing vessels purchasing pollock from U.S. fishermen will be explored below. At this time, then, potential foreign markets for pollock products are uncertain, although the aforementioned import restrictions may be lifted in the future. At the very least, a market presently exists for pollock roe in Japan, sold at a price of $1.00/pound, f.o.b. Petersburg, Alaska.

[9]U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, NMFS. 1977. "International Fisheries Release," 77/99.

VII. RESULTS

The results of the analysis are break-even wholesale pollock block prices under varying production, cost, and discount rate assumptions. Production without roe and production with roe are evaluated for a single cost assumption and a discount rate of r = 0.15. Mixed production is evaluated for three cost assumptions and discount rates of r = 0.10, r = 0.15, and r = 0.20. The frequency distributions of break-even block prices under all assumptions are listed following Appendix Table H.

Production Without Roe

The frequency distribution of the break-even wholesale block price for production without roe is presented as variable 14. The assumption is made that all production during the ten years takes place when the fish do not contain roe. Variable costs are listed in Appendix Table C, and an ex-vessel price of 3¢/pound is used, the price currently paid to fishermen in Petersburg for pollock without roe. For a discount rate of r = 0.15, the frequency distribution of break-even block prices under these conditions is listed as variable 14. The mean break-even price is 44.1097¢/pound, and the standard deviation is 0.0047. The standard deviation is a measure of the degree of dispersion or variation a variable or population exhibits about its mean. A low value of the standard deviation, such as obtained here, indicates that the values are very closely clustered around the mean, or that there is very little variation in the distribution. This is confirmed by the small range of values obtained, 44.0998 to 44.1224, which are the minimum and maximum values of the distribution. For this set of assumptions, the break-even price is approximately 44¢/pound.

Production With Roe

The frequency distribution of the break-even wholesale block price for production with roe is presented as variable 24. It is assumed that all production during the ten years occurs when the pollock contain roe. Variable costs are listed in Appendix Table D, and an ex-vessel price of 5¢/pound is used, the current price paid to fishermen in Petersburg for pollock with roe. The yield of roe is assumed to be 3% of the round weight, with only the proportion of fish going into headed and gutted production producing roe. A roe price is used of $1.00/pound, f.o.b. Petersburg.

For r = 0.15, the mean of the distribution of variable 24 is 53.1812¢/pound and the standard deviation is 0.0047. Again the small standard deviation is an indication of very little variation in the distribution. The range of variable 24 is from 53.1712 to 53.1938. For production with roe and under the stated assumptions, this model yields a break-even wholesale block price of approximately 53¢/pound.

Mixed Production

The remainder of the analysis is undertaken for conditions of mixed production. It is expected that during part of the processing season the pollock will contain roe and that during part of the season the fish will not contain roe. On the basis of discussions with ISI personnel and Alaska Department of Fish and Game biologists in Petersburg, it was decided that it would be reasonable to assume that during 50% of the pollock processing season the fish would contain roe. This assumption is incorporated into the mixed production analysis, and is the basis of the net revenue/pound calculations in Appendix Table G. The assumption is made that the yield of roe is 3% of raw product weight and that the price received for roe is $1.00/pound f.o.b. Petersburg.

The mixed production analysis is performed for three variable cost levels. The ex-vessel pollock prices currently paid in Petersburg are used for the low-range cost assumption, and are subsequently increased for the mid-range and high-range assumptions. For each cost assumption the frequency distribution of break-even pollock block prices is generated for three discount rates, r = 0.10, r = 0.15, and r = 0.20.

Low-Range Cost Assumption

Variables 29, 30, and 31 are the break-even wholesale pollock block prices for different discount rates assuming ex-vessel prices of 3¢/pound for pollock without roe and 5¢/pound for pollock with roe. These are the prices currently paid to fishermen in Petersburg.

Table 5 summarizes the statistical characteristics of variables 29, 30, and 31.

Table 5. Summary statistics for variables 29, 30, and 31, the levels of break-even pollock block prices for mixed production, low-range cost assumption, and varying discount rates.

Variable	r	Mean Price	Standard Deviation	Range of Prices
29	0.10	48.6384	0.0045	48.6297 to 48.6499
30	0.15	48.6454	0.0047	48.6355 to 48.6581
31	0.20	48.6585	0.0060	48.6458 to 48.6763

Again, there is very little dispersion in the distribution of the three variables, as indicated by the small standard deviation. Also, the effect on the break-even block price of increasing the discount rate is very small. For all three discount rates, the break-even pollock block price is between 48.5 and 49.0 cents per pound, which demonstrates the small impact that altering the discount rate has on the break-even block price.

Mid-Range Cost Assumption

Variables 41, 32, and 42 are defined to be the break-even wholesale pollock block prices for varying discount rates and ex-vessel prices of 4¢/pound without roe and 6¢/pound for pollock with roe. Table 6 lists the summary statistics for these variables.

Table 6. Summary statistics for variables 41, 32, and 42, the break-even pollock block prices for mixed production, mid-range cost assumption, and varying discount rates.

Variable	r	Mean Price	Standard Deviation	Range of Prices
41	0.10	55.1319	0.0045	55.1232 to 55.1434
32	0.15	55.1389	0.0047	55.1290 to 55.1516
42	0.20	55.1520	0.0060	55.1393 to 55.1698

Variables 41, 32, and 42 are all distributed very closely about their means, as indicated by the small standard deviations and ranges, both measures of dispersion. Increasing the discount rate increases the mean break-even price by very small amounts. However, increasing ex-vessel prices by 1¢/pound increases the mean break-even pollock block price to 55¢/pound from 48.6¢/pound for the low-range cost assumption.

High-Range Cost Assumption

Variables 43, 33, and 44 are the break-even wholesale pollock block prices for varying discount rates and ex-vessel prices of 5¢/pound for pollock without roe and 7¢/pound for pollock with roe. Table 7 lists the summary statistics for these variables.

Table 7. Summary statistics for variables 43, 33, and 44, the break-even pollock block prices for mixed production, high-range cost assumption, and varying discount rates.

Variable	r	Mean Price	Standard Deviation	Range of Prices
43	0.10	61.6254	0.0045	61.6167 to 61.6369
33	0.15	61.6325	0.0047	61.6225 to 61.6451
44	0.20	61.6455	0.0060	61.6328 to 61.6633

The frequency distributions of these three variables again exhibit very little dispersion, as shown by the small standard deviations and ranges. Varying the discount rate induces very small changes in the break-even wholesale block prices. Increasing the ex-vessel prices from 4¢/pound and 6¢/pound (mid-range cost assumption) to 5¢/pound and 7¢/pound raises the mean break-even wholesale pollock block price to between 61.5 and 62.0¢/pound from 55¢/pound.

Interpretation of Results

The preceding results show the wholesale pollock block prices required to make the net present value of the investment in pollock processing equipment equal to zero, under various cost and discount rate assumptions. If the ex-vessel prices are increased an additional 1¢/pound over the high-range cost assumption, to 6¢ and 8¢/pound, the mean break-even block price for $r = 0.15$ is 68.1260. This is very near the December 1977 pollock block price of 68.0¢/pound, listed in Table 4.

The break-even pollock block price is quite sensitive to increases in the ex-vessel prices paid for pollock. This is due primarily to the fact that the yield of pollock is 22% of raw product weight for blocks and 56% of raw product weight for headed and gutted. Therefore a 1¢/pound change in ex-vessel price has a multiplier-like effect on variable processing costs. The results show that there is a direct relationship between the level of variable costs and the break-even block price. For every 1¢/pound of raw product increase in variable cost, the break-even block price increases by 6.5¢/pound, everything else held constant.

In contrast to the sensitivity of the break-even block price to variable costs, varying the discount rate does not appear to significantly affect the break even block price. This can be seen in Tables 5, 6, and 7. This insensitivity to discount rate changes is due to the particular manner in which the break-even block prices are derived. Recalling equations

$$(9) \qquad Y_i = \frac{C_0 - \frac{SV}{(1+r)^{10}}}{\sum_{t=1}^{10} \frac{V_{it}}{(1+r)^t}}$$

for i = 1,2,..., 95

and (10)

$$Y = 0.154(P_b) - 0.7(VC_b) + 2.856 - 0.3(VC_{hg})$$

helps elucidate the technique used. The values of net revenue/pound of raw product (Y), for which the NPV = 0, obtained by (9) are quite small relative to variable processing costs. For example, the mean value of Y for r = 0.15 is approximately 0.008¢/pound. When r is increased to 0.20, the mean value of Y increases to approximately 0.01¢/pound. These values are quite small in magnitude relative to variable costs of processing, listed in Appendix Tables C and D. Consequently, when these different values of Y are substituted into equation (10), they induce very little change in the value of P_b, the break-even block price.

VIII. SUMMARY AND CONCLUSIONS

The objective of this research is to examine the economics of domestic processing of Alaska pollock in Southeast Alaska. Information pertaining to the production costs of pollock processing and the expected returns to the processor should assist industry and government decision-makers in fisheries development planning.

The economic feasibility of pollock processing is evaluated in a manner which deviates from traditional net present value analysis for two reasons. First, due to the uncertainty regarding future volumes of production, the triangular distribution function and Monte Carlo simulation methods are used to generate a probability distribution of volumes over the next ten years. Secondly, projections of pollock block prices during the ten year investment horizon are not available, necessitating solving the NPV equation for the break-even level of block price. The research resulted in frequency distributions of the break-even levels of pollock block prices under varying production, cost, and discount rate assumptions.

This research focuses upon the production experience of a single firm, Icicle Seafoods Inc., Petersburg, Alaska. The results obtained depend entirely upon the information provided by personnel of ISI. They are applicable to other potential pollock processors in S.E. Alaska only to the extent that their production and marketing relationships are similar to those of ISI. The production cost information used in this research is based upon estimates derived from limited production at the ISI plant. This is no substitute for cost information elicited from extensive production, but was necessary given the time constraints of the study. The production cost estimates are based upon the most reliable information available at the time of the research; further production experience will either validate their accuracy or indicate the need for revision.

Summary

In Chapter II several economic feasibility studies are reviewed. The particular aspects of each study which are relevant to this work are pointed out. The conclusion is reached that the net present value investment criterion is a valid and useful measure of investment worth. Uncertainties with which a pollock processor must deal are discussed in Chapter III. It is found that supply variability is the most significant source of uncertainty, although pollock markets, new technology, and the institutional environment may also cause uncertainty for the processor. In Chapter IV the methodology utilized in this research is explained. Using the volume estimates as provided in Appendix Table A, and the Monte Carlo generated 95 randomly determined values of F(x), equations

$$x = a + [F(x)(c-a)(b-a)]^{\frac{1}{2}}, \quad a \leq x \leq b \tag{5}$$

and

$$x = c - [(1 - F(x))(c-a)(c-b)]^{\frac{1}{2}}, \quad b \leq x \leq c \tag{6}$$

are utilized to generate volume distributions for the years 1978-1987. These volume distributions are subsequently inserted into equation

$$Y_i = \frac{C_0 - \frac{SV}{(1+r)^{10}}}{\sum_{t=1}^{10} \frac{V_{it}}{(1+r)^t}} \tag{9}$$

yielding the frequency distribution of Y, the net revenue/pound of raw product for which the NPV of the investment equals zero at a given discount rate. These values of Y are then used in equation

$$Y = 0.154(P_b) - 0.7(VC_b) + 2.856 - 0.3(VC_{hg}) \tag{10}$$

to give the distribution of break-even wholesale block prices, P_b, for given production and cost assumptions. The results obtained are frequency distributions of wholesale pollock block prices at which the NPV of the investment equals zero, under various production, cost, and discount rate assumptions. These results are presented in the computer printouts following Appendix Table H. The presently available information pertaining to the pollock resource in S.E. Alaska is presented in Chapter V. The conclusion is reached that many gaps in our knowledge of the resource still exist, and that a final statement as to the ability of the resource to support a commercial fishery cannot be made. In Chapter VI a brief discussion of the U.S. market for pollock blocks is provided to acquaint the reader with the price and quantity trends exhibited by pollock products during recent years. Finally, in Chapter VII the results of the analysis, the break-even wholesale block prices under various assumptions, are presented and briefly discussed. It is noted that the break-even block prices are quite sensitive to changes in variable costs, but rather insensitive to changes in the discount rate.

Conclusions

An economic feasibility study or analysis usually must be undertaken in the absence of complete information. The economic feasibility of pollock processing in S.E. Alaska has been evaluated on the basis of the best production cost estimates available during the time of the research. In addition, future volumes of production have been estimated by the two sources judged to be the most knowledgeable in this area. As a consequence, one cannot view the results with certitude, but as order-of-magnitude estimates of the cost and return relationships expected in pollock processing operations.

Pollock processing in S.E. Alaska appears to be economically feasible under all sets of assumptions evaluated. The December 1977 wholesale price of frozen Alaska pollock blocks, as quoted in the Market News Report, Boston, Mass. is 68.0¢/pound. The break-even wholesale pollock block prices, for the mixed production analysis, are 48.6, 55.1, and 61.6¢/pound, for the low-range, mid-range, and high range cost assumptions respectively. The low-range cost assumption uses the ex-vessel prices currently paid to fishermen in Petersburg as the basis of the variable cost calculations. The implication is that even if the processing costs are understated via the estimates, pollock processing is still economically feasible at the current level of ex-vessel prices.

As indicated in Table 4, there has been considerable variation in wholesale pollock block prices over the past four years. Given this variability in price, the decision to use the current wholesale price of 68¢/pound for feasibility determination may appear unwarranted, and the conclusion that pollock processing is economically feasible too strongly stated. However, the decision to use a wholesale block price of 68¢/pound is based upon the following justifications. First, the world-wide extension of coastal nation's jurisdiction to 200 miles vitally affects the two main suppliers of Alaska pollock blocks to the U.S. As detailed in Chapter VI, both Japan and Korea face severe reductions in the allowable harvest of pollock from waters of the USSR. Since the USSR does not export fisheries products to the U.S., the expected effect of these quota restrictions will be to help maintain wholesale prices of Alaska pollock blocks at the current record levels. Secondly, the wholesale price of cod blocks, one of the main substitutes for pollock blocks, is also at record levels. Cod block prices will probably not fall appreciably in upcoming years, due to severe quota restrictions on all fleets in the North Atlantic precipitated by the biologically depressed state of cod stocks in that area. Finally, the increasing demand for fish portions by fast-food enterprises should also serve to maintain all fish block prices at their current levels.

This analysis indicates that in order for the break-even block price to equal the current market price, ex-vessel prices of 6¢/pound for fish without roe and 8¢/pound for fish with roe would have to be paid to the fishermen.

The NPV equation is solved for the level of P_b at which the net present value of the investment equals zero under a given set of assumptions. Therefore the break-even wholesale block price becomes the dependent variable in the model, derived for given levels of the independent variables. Several of the independent variables are assumed constant in this model at the levels listed in Table 8.

Table 8. Values of the independent variables which are held constant throughout the pollock processing feasibility analysis.

Independent Variable	Constant Value
Proportion of pollock suitable for filleting	70%
Yield on blocks	22%
Variable costs of processing blocks, exclusive of raw product	6.68¢/pound of raw product
Proportion of pollock suitable for headed and gutted production	30%
Yield on headed and gutted	56¢
Variable costs of processing headed, and gutted, without roe, exclusive of raw product	6.55¢/pound of raw product
Pollock roe price	$1.00/pound
Roe yield	3%
Variable costs of processing headed and gutted, with roe, exclusive of raw product	7.54¢/pound of raw product
Capital outlay required	$131,750.00

The volumes of production during the ten years, the discount rate, and ex-vessel prices are allowed to vary in the analysis. Volume distributions are determined via the triangular distribution and Monte Carlo simulation methods. Varying the discount rate has little effect on the break-even block price. However, there is a direct relationship between the ex-vessel pollock prices and the break-even block price. This is depicted graphically for mixed production in Figure 6.

The sensitivity of the break-even wholesale block price to variable costs under all sets of assumptions needs to be underscored. The implication for the pollock processor is that there exist very strong incentives to achieve increases in efficiency throughout the processing operation. This can be achieved by either reducing the labor costs/pound of raw product or by increasing the yield on blocks or headed and gutted pollock. Either measure would lower the break-even pollock block price. It is also evident that the capital costs incurred to establish a pollock processing line are relatively small compared to the variable costs of production over the ten year investment horizon.

The institutional environment in which a pollock processor must make decisions is a source of uncertainty. Two issues are of particular importance to processors interested in groundfish development in Alaska. The first is whether or not foreign joint-ventures are allowed by the North Pacific Fisheries Management Council and the Department of Commerce to operate in Alaska. Should joint-ventures be authorized to purchase pollock from U.S. fishermen, the ex-vessel pollock price may be bid upward. This

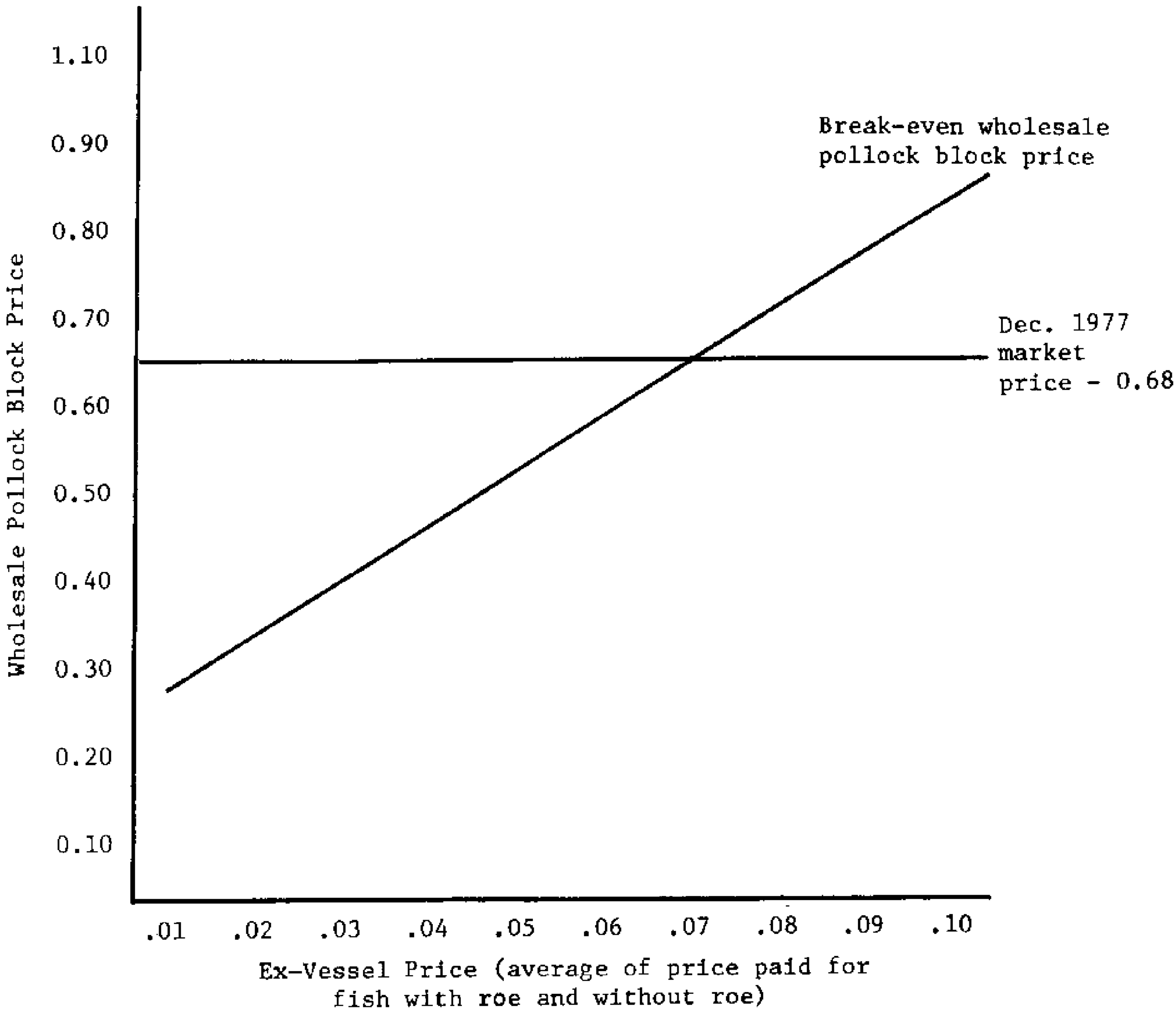

Figure 1. Break-even wholesale pollock block prices for various ex-vessel price levels: mixed production.

research indicates that higher ex-vessel prices increases the break-even wholesale block price, everything else remaining equal. The second item of interest to a pollock processor is the level of government involvement in fisheries development. If government or joint industry-government sponsored commercial fishing trials materialize, some of the uncertainty regarding supply availability may be reduced.

Limitations of the Research

Changes in any of the assumptions employed in the analysis would quite expectedly alter the results obtained. The assumptions incorporated in this research are based on information supplied by personnel of ISI, and it is hoped are as realistic as possible. However, the accuracy of the results does depend in large part on the validity of the assumptions underlying the analysis.

Another limitation of this work is the reliance upon the production cost information of but a single firm. Although ISI was the only U.S. processor handling pollock at the time of this research, their experience is bound to be somewhat unique. Due to the particular location of the Petersburg plant and the management capability of the ISI personnel, the information obtained in this research will differ somewhat than that generated from a similar undertaking by another firm in S.E. Alaska.

Finally, it should be reiterated that the cost information used in this analysis is derived from estimates based on limited production. The accuracy of the results clearly depends on the accuracy of these production cost estimates.

Suggestions for Further Research

Several issues relevant to the economic feasibility of pollock processing have not been definitively resolved in this research. Time and resource constraints have precluded consideration of the following areas, each the legitimate topic of a separate research effort. The economic feasibility of harvesting pollock needs to be addressed, focusing perhaps on the opportunity cost of fishing for pollock versus other trawl species. An analysis of the domestic and foreign demand for pollock products would be a valuable addition to the information generated in this research. Lastly, a comparison of the economics of shore-based and floating pollock processing operations would complement the results obtained in this work.

This research uses the triangular distribution function to partially account for the uncertainty regarding future volumes of pollock production. To the author's knowledge this is the first application of this technique to a problem in the fisheries. In an area such as fisheries where uncertainty continually prevails, the triangular distribution can be a useful aid to rational decision-making under conditions of imperfect knowledge.

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APPENDICES

Table A. Estimates of future volumes of pollock production of ISI Plant, Petersburg, Alaska, by ISI personnel and Alaska Department of Fish and Game (ADF&G) Biologist, 1978-1987.

Year	Minimum	Most Likely	Maximum
	ISI ESTIMATES (pounds, round weight)		
1978	400,000	750,000	2,000,000
1979	700,000	1,500,000	5,000,000
1980	1,000,000	2,500,000	5,000,000
1981	1,000,000	3,000,000	5,000,000
1982	1,000,000	3,000,000	6,000,000
1983	1,000,000	4,000,000	6,000,000
1984	1,000,000	4,000,000	6,000,000
1985	1,000,000	4,000,000	6,000,000
1986	1,000,000	5,000,000	7,000,000
1987	1,000,000	6,000,000	10,000,000
	ADF&G ESTIMATES (pounds, round weight)		
1978	500,000	1,500,000	3,500,000
1979	1,000,000	2,000,000	5,000,000
1980	1,500,000	2,500,000	6,000,000
1981	1,500,000	3,000,000	6,000,000
1982	1,500,000	3,500,000	7,500,000
1983	2,000,000	4,000,000	8,000,000
1984	2,000,000	4,500,000	8,000,000
1985	2,000,000	5,000,000	8,000,000
1986	2,000,000	5,000,000	8,000,000
1987	2,000,000	5,000,000	8,000,000
	AVERAGE OF ISI AND ADF&G ESTIMATES		
1978	450,000	1,125,000	2,750,000
1979	850,000	1,750,000	5,000,000
1980	1,250,000	2,500,000	5,500,000
1981	1,250,000	3,000,000	5,500,000
1982	1,250,000	3,250,000	6,750,000
1983	1,500,000	4,000,000	7,000,000
1984	1,500,000	4,250,000	7,000,000
1985	1,500,000	4,500,000	7,000,000
1986	1,500,000	5,000,000	7,500,000
1987	1,500,000	5,500,500	9,000,000

Table B. Capital costs incurred to establish pollock processing line at ISI Plant, Petersburg, Alaska.

Item	Cost
One ARENCO CUB header (used)	$ 6,000.00
One ARENCO CIV header	15,000.00
Two ARENCO SFA-4 fillet and skinning machines, @ $30,800.00	61.600.00
Belts, conveyors, etc.	5,000.00
Freezer forms	4,150.00
Processing room conversion	40,000.00
TOTAL CAPITAL COSTS	$131,750.00

Table C. Variable costs of pollock production, without roe, exclusive of raw product cost.

	Item	¢/lb. of raw product
Block Production		
	Labor	2.9
	Power & Water	0.15
	Packaging	0.44
	Shipping	0.44
	Sales	0.75
	Indirect costs	2.0
	Variable costs, Blocks	6.68
Headed & Gutted Production		
	Labor	3.08
	Power & Water	0.15
	Packaging	0.84
	Shipping	--
	Sales	0.48
	Indirect costs	2.0
	Variable costs, H&G	6.55

Table D. Variable costs of pollock production, with roe, exclusive of raw product cost.

Item	¢/lb. of raw product
Block Production	
Labor	2.9
Power & Water	0.15
Packaging	0.44
Shipping	0.44
Sales	0.75
Indirect costs	2.0
Variable costs, Blocks	6.68
Headed & Gutted Production	
Labor	3.92
Power & Water	0.15
Packaging	0.84
Shipping	--
Sales	0.63
Indirect costs	2.0
Variable costs, H&G	7.54

Table E. Calculation of net revenue/pound of raw product (Y) for varying cost assumptions: production without roe.

$$Y = a(C(P_b) - VC_b) + b(d(P_{hg}) - VC_{hg})$$

where: Y = net revenue/pound of raw product

a = proportion of raw product going into block production, 0.7

c = yield on blocks, 0.22

P_b = wholesale price for frozen pollock blocks

VC_b = variable costs of producing blocks, in ¢/pound of raw product

b = proportion of raw product going into headed and gutted production, 0.3

d = yield on headed and gutted product, 0.56

P_{hg} = wholesale price for headed and gutted, 17¢/lb.

VC_{hg} = variable costs of producing headed and gutted product, in ¢/lb. raw product

Ex-Vessel Price	Net Revenue/Pound
3¢/lb.	$Y = 0.154\ (P_b) - 6.785$
4¢/lb.	$Y = 0.154\ (P_b) - 7.785$
5¢/lb.	$Y = 0.154\ (P_b) - 8.785$

Table F. Calculation of net revenue/pound of raw product (Y) for varying cost assumptions: production with roe.

$$Y = a(c(P_b) - VC_b) + b(d(P_{hg}) + e(P_r) - VC_{hg})$$

where: Y, a, c, P_b, VC_b, b, d, P_{hg}, and VC_{hg} are as in Table E, and

e = yield of roe, 0.03

P_r = wholesale price of roe, \$1.00/lb.

Ex-Vessel Price	Net Revenue/Pound
5¢/lb.	$Y = 0.154\ (P_b) - 8.182$
6¢/lb.	$Y = 0.154\ (P_b) - 9.182$
7¢/lb.	$Y = 0.154\ (P_b) - 10.182$

Table G. Calculation of net revenue/pound of raw product (Y) for varying cost assumptions: mixed production.

$$Y = f[a(c(P_b) - VC_b) + b(d(P_{hg}) - VC_{hg})]$$

$$+ g[a(c(P_b) - VC_b) + b(d(P_{hg}) + e(P_r) - VC_{hg})]$$

where: Y, a, c, P_b, VC_b, b, d, P_{hg}, VC_{hg}, e, and P_r are as defined in Tables E and F, and

f = proportion of processing season when pollock do not contain roe, 0.5

g = proportion of processing season when pollock do contain roe, 0.5

Ex-Vessel Prices	Net Revenue/Pound
3¢/lb. without roe 5¢/lb. with roe	$Y = 0.154\ (P_b) - 7.4835$
4¢/lb. without roe 6¢/lb. with roe	$Y = 0.154\ (P_b) - 8.4835$
5¢/lb. without roe 7¢/lb. with roe	$Y = 0.154\ (P_b) - 9.4835$

Table H. Explanation of computer printout: definition of variable numbers for which frequency distribution, mean, and standard deviation are listed. All variables represent the wholesale pollock block price for which the NPV = 0 under various production, ex-vessel price, and discount rate assumptions.

Variable	Production	Ex-Vessel Price	Discount Rate
14	w/o roe	3¢	0.15
24	w roe	5¢	0.15
29	mixed	3¢, 5¢	0.10
30	mixed	3¢, 5¢	0.15
31	mixed	3¢, 5¢	0.20
41	mixed	4¢, 6¢	0.10
32	mixed	4¢, 6¢	0.15
42	mixed	4¢, 6¢	0.20
43	mixed	5¢, 7¢	0.10
33	mixed	5¢, 7¢	0.15
44	mixed	5¢, 7¢	0.20

```
0$VAR,50
0$READ,BREAK,1-44
0$TTYOFF
0$FREQ,14
 LOWER BOUND FOR FIRST INTERVAL:          4.409978E 01
 NUMBER OF INTERVALS (<51):      15
 INTERVAL SIZE:          1.612357E-03
                    FREQUENCY DISTRIBUTION
                         VARIABLE 14
                         UP TO BUT                  PERCENT
 INT       FROM        NOT INCLUDING   FREQUENCY     FREQ
  1     4.40998E 01    4.41014E 01          4         4.211
  2     4.41014E 01    4.41030E 01          3         3.158
  3     4.41030E 01    4.41046E 01          4         4.211
  4     4.41046E 01    4.41062E 01         10        10.526
  5     4.41062E 01    4.41078E 01         14        14.737
  6     4.41078E 01    4.41095E 01         11        11.579
  7     4.41095E 01    4.41111E 01         13        13.684
  8     4.41111E 01    4.41127E 01         11        11.579
  9     4.41127E 01    4.41143E 01          9         9.474
 10     4.41143E 01    4.41159E 01          7         7.368
 11     4.41159E 01    4.41175E 01          2         2.105
 12     4.41175E 01    4.41191E 01          4         4.211
 13     4.41191E 01    4.41207E 01          2         2.105
 14     4.41207E 01    4.41224E 01          0         0
 15     4.41224E 01    4.41240E 01          1         1.053
-                CUMULATIVE FREQUENCY DISTRIBUTION
                         VARIABLE 14
                             NUMBER LESS   PERCENT LESS
 INTERVAL          VALUE      THAN VALUE    THAN VALUE
      1          4.41014E 01        4           4.211
      2          4.41030E 01        7           7.368
      3          4.41046E 01       11          11.579
      4          4.41062E 01       21          22.105
      5          4.41078E 01       35          36.842
      6          4.41095E 01       46          48.421
      7          4.41111E 01       59          62.105
      8          4.41127E 01       70          73.684
      9          4.41143E 01       79          83.158
     10          4.41159E 01       86          90.526
     11          4.41175E 01       88          92.632
     12          4.41191E 01       92          96.842
     13          4.41207E 01       94          98.947
     14          4.41224E 01       94          98.947
     15          4.41240E 01       95         100.000
0$MEAN,14
 14          :    44.10972636
0$STDEV,14
 14          :    0.004705957
```

```
LOWER BOUND FOR FIRST INTERVAL:          5.317121E 01
NUMBER OF INTERVALS (<51):      15
INTERVAL-SIZE:                  1.612357E-03
```

FREQUENCY DISTRIBUTION
VARIABLE 24

INT	FROM	UP TO BUT NOT INCLUDING	FREQUENCY	PERCENT FREQ
1	5.31712E 01	5.31728E 01	4	4.211
2	5.31728E 01	5.31744E 01	3	3.158
3	5.31744E 01	5.31760E 01	4	4.211
4	5.31760E 01	5.31777E 01	10	10.526
5	5.31777E 01	5.31793E 01	14	14.737
6	5.31793E 01	5.31809E 01	11	11.579
7	5.31809E 01	5.31825E 01	13	13.684
8	5.31825E 01	5.31841E 01	11	11.579
9	5.31841E 01	5.31857E 01	9	9.474
10	5.31857E 01	5.31873E 01	7	7.368
11	5.31873E 01	5.31889E 01	2	2.105
12	5.31889E 01	5.31906E 01	4	4.211
13	5.31906E 01	5.31922E 01	2	2.105
14	5.31922E 01	5.31938E 01	0	0
15	5.31938E 01	5.31954E 01	1	1.053

CUMULATIVE FREQUENCY DISTRIBUTION
VARIABLE 24

INTERVAL	VALUE	NUMBER LESS THAN VALUE	PERCENT LESS THAN VALUE
1	5.31728E 01	4	4.211
2	5.31744E 01	7	7.368
3	5.31760E 01	11	11.579
4	5.31777E 01	21	22.105
5	5.31793E 01	35	36.842
6	5.31809E 01	46	48.421
7	5.31825E 01	59	62.105
8	5.31841E 01	70	73.684
9	5.31857E 01	79	83.158
10	5.31873E 01	86	90.526
11	5.31889E 01	88	92.632
12	5.31906E 01	92	96.842
13	5.31922E 01	94	98.947
14	5.31938E 01	94	98.947
15	5.31954E 01	95	100.000

```
0$MEAN,24
 24        :   53.18115494
0$STDEV,24
 24        :   0.004705964
```

```
LOWER BOUND FOR FIRST INTERVAL:          4.862970E 01
NUMBER OF INTERVALS (<51):    15
INTERVAL SIZE:          1.439107E-03
```

FREQUENCY DISTRIBUTION
VARIABLE 29

INT	FROM	UP TO BUT NOT INCLUDING	FREQUENCY	PERCENT FREQ
1	4.86297E 01	4.86311E 01	2	2.105
2	4.86311E 01	4.86326E 01	4	4.211
3	4.86326E 01	4.86340E 01	10	10.526
4	4.86340E 01	4.86355E 01	12	12.632
5	4.86355E 01	4.86369E 01	10	10.526
6	4.86369E 01	4.86383E 01	12	12.632
7	4.86383E 01	4.86398E 01	10	10.526
8	4.86398E 01	4.86412E 01	11	11.579
9	4.86412E 01	4.86427E 01	9	9.474
10	4.86427E 01	4.86441E 01	6	6.316
11	4.86441E 01	4.86455E 01	2	2.105
12	4.86455E 01	4.86470E 01	2	2.105
13	4.86470E 01	4.86484E 01	3	3.158
14	4.86484E 01	4.86499E 01	2	2.105
15	4.86499E 01	4.86513E 01	0	0

CUMULATIVE FREQUENCY DISTRIBUTION
VARIABLE 29

INTERVAL	VALUE	NUMBER LESS THAN VALUE	PERCENT LESS THAN VALUE
1	4.86311E 01	2	2.105
2	4.86326E 01	6	6.316
3	4.86340E 01	16	16.842
4	4.86355E 01	28	29.474
5	4.86369E 01	38	40.000
6	4.86383E 01	50	52.632
7	4.86398E 01	60	63.158
8	4.86412E 01	71	74.737
9	4.86427E 01	80	84.211
10	4.86441E 01	86	90.526
11	4.86455E 01	88	92.632
12	4.86470E 01	90	94.737
13	4.86484E 01	93	97.895
14	4.86499E 01	95	100.000
15	4.86513E 01	95	100.000

```
0$MEAN,29
 29        :    48.63840856
0$STDEV,29
 29        :    0.004481372
```

LOWER BOUND FOR FIRST INTERVAL: 4.863549E 01
NUMBER OF INTERVALS (<51): 15
INTERVAL SIZE: 1.612357E-03

FREQUENCY DISTRIBUTION
VARIABLE 30

INT	FROM	UP TO BUT NOT INCLUDING	FREQUENCY	PERCENT FREQ
1	4.86355E 01	4.86371E 01	4	4.211
2	4.86371E 01	4.86387E 01	3	3.158
3	4.86387E 01	4.86403E 01	4	4.211
4	4.86403E 01	4.86419E 01	10	10.526
5	4.86419E 01	4.86436E 01	14	14.737
6	4.86436E 01	4.86452E 01	11	11.579
7	4.86452E 01	4.86468E 01	13	13.684
8	4.86468E 01	4.86484E 01	11	11.579
9	4.86484E 01	4.86500E 01	9	9.474
10	4.86500E 01	4.86516E 01	7	7.368
11	4.86516E 01	4.86532E 01	2	2.105
12	4.86532E 01	4.86548E 01	4	4.211
13	4.86548E 01	4.86565E 01	2	2.105
14	4.86565E 01	4.86581E 01	0	0
15	4.86581E 01	4.86597E 01	1	1.053

CUMULATIVE FREQUENCY DISTRIBUTION
VARIABLE 30

INTERVAL	VALUE	NUMBER LESS THAN VALUE	PERCENT LESS THAN VALUE
1	4.86371E 01	4	4.211
2	4.86387E 01	7	7.368
3	4.86403E 01	11	11.579
4	4.86419E 01	21	22.105
5	4.86436E 01	35	36.842
6	4.86452E 01	46	48.421
7	4.86468E 01	59	62.105
8	4.86484E 01	70	73.684
9	4.86500E 01	79	83.158
10	4.86516E 01	86	90.526
11	4.86532E 01	88	92.632
12	4.86548E 01	92	96.842
13	4.86565E 01	94	98.947
14	4.86581E 01	94	98.947
15	4.86597E 01	95	100.000

0$MEAN,30
30 : 48.6544864
0$STDEV,30
30 : 0.004705963

```
LOWER BOUND FOR FIRST INTERVAL:          4.864583E-01
NUMBER OF INTERVALS (<51):        15
INTERVAL SIZE:              2.174264E-03
```

FREQUENCY DISTRIBUTION
VARIABLE 31

INT	FROM	UP TO BUT NOT INCLUDING	FREQUENCY	PERCENT FREQ
1	4.86458E 01	4.86480E 01	4	4.211
2	4.86480E 01	4.86502E 01	3	3.158
3	4.86502E 01	4.86523E 01	9	9.474
4	4.86523E 01	4.86545E 01	9	9.474
5	4.86545E 01	4.86567E 01	14	14.737
6	4.86567E 01	4.86589E 01	11	11.579
7	4.86589E 01	4.86610E 01	16	16.842
8	4.86610E 01	4.86632E 01	8	8.421
9	4.86632E 01	4.86654E 01	10	10.526
10	4.86654E 01	4.86676E 01	3	3.158
11	4.86676E 01	4.86697E 01	4	4.211
12	4.86697E 01	4.86719E 01	2	2.105
13	4.86719E 01	4.86741E 01	1	1.053
14	4.86741E 01	4.86763E 01	0	0
15	4.86763E 01	4.86784E 01	1	1.053

CUMULATIVE FREQUENCY DISTRIBUTION
VARIABLE 31

INTERVAL	VALUE	NUMBER LESS THAN VALUE	PERCENT LESS THAN VALUE
1	4.86480E 01	4	4.211
2	4.86502E 01	7	7.368
3	4.86523E 01	16	16.842
4	4.86545E 01	25	26.316
5	4.86567E 01	39	41.053
6	4.86589E 01	50	52.632
7	4.86610E 01	66	69.474
8	4.86632E 01	74	77.895
9	4.86654E 01	84	88.421
10	4.86676E 01	87	91.579
11	4.86697E 01	91	95.789
12	4.86719E 01	93	97.895
13	4.86741E 01	94	98.947
14	4.86763E 01	94	98.947
15	4.86784E 01	95	100.000

```
0$MEAN,31
 31         :    48.65853410
0$STDEV,31
 31         :    0.00603451O
```

LOWER BOUND FOR FIRST INTERVAL: 5.512321E 01

NUMBER OF INTERVALS (<51): 15
INTERVAL SIZE: 1.439107E-03

FREQUENCY DISTRIBUTION
VARIABLE 41

INT	FROM	UP TO BUT NOT INCLUDING	FREQUENCY	PERCENT FREQ
1	5.51232E 01	5.51246E 01	2	2.105
2	5.51246E 01	5.51261E 01	4	4.211
3	5.51261E 01	5.51275E 01	10	10.526
4	5.51275E 01	5.51290E 01	12	12.632
5	5.51290E 01	5.51304E 01	10	10.526
6	5.51304E 01	5.51318E 01	12	12.632
7	5.51318E 01	5.51333E 01	10	10.526
8	5.51333E 01	5.51347E 01	11	11.579
9	5.51347E 01	5.51362E 01	9	9.474
10	5.51362E 01	5.51376E 01	6	6.316
11	5.51376E 01	5.51390E 01	2	2.105
12	5.51390E 01	5.51405E 01	2	2.105
13	5.51405E 01	5.51419E 01	3	3.158
14	5.51419E 01	5.51434E 01	2	2.105
15	5.51434E 01	5.51448E 01	0	0

CUMULATIVE FREQUENCY DISTRIBUTION
VARIABLE 41

INTERVAL	VALUE	NUMBER LESS THAN VALUE	PERCENT LESS THAN VALUE
1	5.51246E 01	2	2.105
2	5.51261E 01	6	6.316
3	5.51275E 01	16	16.842
4	5.51290E 01	28	29.474
5	5.51304E 01	38	40.000
6	5.51318E 01	50	52.632
7	5.51333E 01	60	63.158
8	5.51347E 01	71	74.737
9	5.51362E 01	80	84.211
10	5.51376E 01	86	90.526
11	5.51390E 01	88	92.632
12	5.51405E 01	90	94.737
13	5.51419E 01	93	97.895
14	5.51434E 01	95	100.000
15	5.51448E 01	95	100.000

```
0$MEAN,41
 41        :  55.13191506
0$STDEV,41
 41        :  0.004481369
```

```
LOWER BOUND FOR FIRST INTERVAL:          5.512900E 01
NUMBER OF INTERVALS (<51):      15
INTERVAL SIZE:            1.612357E-03
                    FREQUENCY DISTRIBUTION
                        VARIABLE 32
                        UP TO BUT                    PERCENT
INT       FROM        NOT INCLUDING   FREQUENCY       FREQ
 1     5.51290E 01    5.51306E 01          4          4.211
 2     5.51306E 01    5.51322E 01          3          3.158
 3     5.51322E 01    5.51338E 01          4          4.211
 4     5.51338E 01    5.51354E 01         10         10.526
 5     5.51354E 01    5.51371E 01         14         14.737
 6     5.51371E 01    5.51387E 01         11         11.579
 7     5.51387E 01    5.51403E 01         13         13.684
 8     5.51403E 01    5.51419E 01         11         11.579
 9     5.51419E 01    5.51435E 01          9          9.474
10     5.51435E 01    5.51451E 01          7          7.368
11     5.51451E 01    5.51467E 01          2          2.105
12     5.51467E 01    5.51483E 01          4          4.211
13     5.51483E 01    5.51500E 01          2          2.105
14     5.51500E 01    5.51516E 01          0              0
15     5.51516E 01    5.51532E 01          1          1.053
                CUMULATIVE FREQUENCY DISTRIBUTION
                        VARIABLE 32
                                NUMBER LESS   PERCENT LESS
INTERVAL          VALUE         THAN VALUE     THAN VALUE
      1        5.51306E 01           4            4.211
      2        5.51322E 01           7            7.368
      3        5.51338E 01          11           11.579
      4        5.51354E 01          21           22.105
      5        5.51371E 01          35           36.842
      6        5.51387E 01          46           48.421
      7        5.51403E 01          59           62.105
      8        5.51419E 01          70           73.684
      9        5.51435E 01          79           83.158
     10        5.51451E 01          86           90.526
     11        5.51467E 01          88           92.632
     12        5.51483E 01          92           96.842
     13        5.51500E 01          94           98.947


     14        5.51516E 01          94           98.947
     15        5.51532E 01          95          100.000
0$MEAN,32
  32       :   55.13894714
0$STDEV,32
  32       :   0.004705963
```

LOWER BOUND FOR FIRST INTERVAL: 5.513933E 01
NUMBER OF INTERVALS (<51): 15
INTERVAL SIZE: 2.174264E-03

FREQUENCY DISTRIBUTION
VARIABLE 42

INT	FROM	UP TO BUT NOT INCLUDING	FREQUENCY	PERCENT FREQ
1	5.51393E 01	5.51415E 01	4	4.211
2	5.51415E 01	5.51437E 01	3	3.158
3	5.51437E 01	5.51459E 01	9	9.474
4	5.51459E 01	5.51480E 01	9	9.474
5	5.51480E 01	5.51502E 01	14	14.737
6	5.51502E 01	5.51524E 01	11	11.579
7	5.51524E 01	5.51546E 01	16	16.842
8	5.51546E 01	5.51567E 01	8	8.421
9	5.51567E 01	5.51589E 01	10	10.526
10	5.51589E 01	5.51611E 01	3	3.158
11	5.51611E 01	5.51632E 01	4	4.211
12	5.51632E 01	5.51654E 01	2	2.105
13	5.51654E 01	5.51676E 01	1	1.053
14	5.51676E 01	5.51698E 01	0	0
15	5.51698E 01	5.51719E 01	1	1.053

CUMULATIVE FREQUENCY DISTRIBUTION
VARIABLE 42

INTERVAL	VALUE	NUMBER LESS THAN VALUE	PERCENT LESS THAN VALUE
1	5.51415E 01	4	4.211
2	5.51437E 01	7	7.368
3	5.51459E 01	16	16.842
4	5.51480E 01	25	26.316
5	5.51502E 01	39	41.053
6	5.51524E 01	50	52.632
7	5.51546E 01	66	69.474
8	5.51567E 01	74	77.895
9	5.51589E 01	84	88.421
10	5.51611E 01	87	91.579
11	5.51632E 01	91	95.789
12	5.51654E 01	93	97.895
13	5.51676E 01	94	98.947
14	5.51698E 01	94	98.947
15	5.51719E 01	95	100.000

0$MEAN,42
42 : 55.15204060
0$STDEV,42
42 : 0.006034510

LOWER BOUND FOR FIRST INTERVAL: 6.161672E 01
NUMBER OF INTERVALS (<51): 15
INTERVAL SIZE: 1.439107E-03

FREQUENCY DISTRIBUTION
VARIABLE 43

INT	FROM	UP TO BUT NOT INCLUDING	FREQUENCY	PERCENT FREQ
1	6.16167E 01	6.16182E 01	2	2.105
2	6.16182E 01	6.16196E 01	4	4.211
3	6.16196E 01	6.16210E 01	10	10.526
4	6.16210E 01	6.16225E 01	12	12.632
5	6.16225E 01	6.16239E 01	10	10.526
6	6.16239E 01	6.16254E 01	12	12.632
7	6.16254E 01	6.16268E 01	10	10.526
8	6.16268E 01	6.16282E 01	11	11.579
9	6.16282E 01	6.16297E 01	9	9.474
10	6.16297E 01	6.16311E 01	6	6.316
11	6.16311E 01	6.16325E 01	2	2.105
12	6.16325E 01	6.16340E 01	2	2.105
13	6.16340E 01	6.16354E 01	3	3.158
14	6.16354E 01	6.16369E 01	2	2.105
15	6.16369E 01	6.16383E 01	0	0

CUMULATIVE FREQUENCY DISTRIBUTION
VARIABLE 43

INTERVAL	VALUE	NUMBER LESS THAN VALUE	PERCENT LESS THAN VALUE
1	6.16182E 01	2	2.105
2	6.16196E 01	6	6.316
3	6.16210E 01	16	16.842
4	6.16225E 01	28	29.474
5	6.16239E 01	38	40.000
6	6.16254E 01	50	52.632
7	6.16268E 01	60	63.158
8	6.16282E 01	71	74.737
9	6.16297E 01	80	84.211
10	6.16311E 01	86	90.526
11	6.16325E 01	88	92.632
12	6.16340E 01	90	94.737
13	6.16354E 01	93	97.895
14	6.16369E 01	95	100.000
15	6.16383E 01	95	100.000

```
0$MEAN,43
 43      :   61.62542156
0$STDEV,43
 43      :   0.00448136
```

```
LOWER BOUND FOR FIRST INTERVAL:            6.162251E 01
NUMBER OF INTERVALS (<51):        15
INTERVAL SIZE:              1.612357E-03
```

FREQUENCY DISTRIBUTION
VARIABLE 33

INT	FROM	UP TO BUT NOT INCLUDING	FREQUENCY	PERCENT FREQ
1	6.16225E 01	6.16241E 01	4	4.211
2	6.16241E 01	6.16257E 01	3	3.158
3	6.16257E 01	6.16273E 01	4	4.211
4	6.16273E 01	6.16290E 01	10	10.526
5	6.16290E 01	6.16306E 01	14	14.737
6	6.16306E 01	6.16322E 01	11	11.579
7	6.16322E 01	6.16338E 01	13	13.684
8	6.16338E 01	6.16354E 01	11	11.579
9	6.16354E 01	6.16370E 01	9	9.474
10	6.16370E 01	6.16386E 01	7	7.368
11	6.16386E 01	6.16402E 01	2	2.105
12	6.16402E 01	6.16419E 01	4	4.211
13	6.16419E 01	6.16435E 01	2	2.105
14	6.16435E 01	6.16451E 01	0	0
15	6.16451E 01	6.16467E 01	1	1.053

CUMULATIVE FREQUENCY DISTRIBUTION
VARIABLE 33

INTERVAL	VALUE	NUMBER LESS THAN VALUE	PERCENT LESS THAN VALUE
1	6.16241E 01	4	4.211
2	6.16257E 01	7	7.368
3	6.16273E 01	11	11.579
4	6.16290E 01	21	22.105
5	6.16306E 01	35	36.842
6	6.16322E 01	46	48.421
7	6.16338E 01	59	62.105
8	6.16354E 01	70	73.684
9	6.16370E 01	79	83.158
10	6.16386E 01	86	90.526
11	6.16402E 01	88	92.632
12	6.16419E 01	92	96.842
13	6.16435E 01	94	98.947
14	6.16451E 01	94	98.947
15	6.16467E 01	95	100.000

```
0$MEAN,33
 33       :   61.63245364
0$STDEV,33
 33       :   0.004705966
```

```
LOWER BOUND FOR FIRST INTERVAL:            6.163284E-01
NUMBER OF INTERVALS (<51):     15
INTERVAL SIZE:            2.174264E-03
```

FREQUENCY DISTRIBUTION
VARIABLE 44

INT	FROM	UP TO BUT NOT INCLUDING	FREQUENCY	PERCENT FREQ
1	6.16328E 01	6.16350E 01	4	4.211
2	6.16350E 01	6.16372E 01	3	3.158
3	6.16372E 01	6.16394E 01	9	9.474
4	6.16394E 01	6.16415E 01	9	9.474
5	6.16415E 01	6.16437E 01	14	14.737
6	6.16437E 01	6.16459E 01	11	11.579
7	6.16459E 01	6.16481E 01	16	16.842
8	6.16481E 01	6.16502E 01	8	8.421
9	6.16502E 01	6.16524E 01	10	10.526
10	6.16524E 01	6.16546E 01	3	3.158
11	6.16546E 01	6.16568E 01	4	4.211
12	6.16568E 01	6.16589E 01	2	2.105
13	6.16589E 01	6.16611E 01	1	1.053
14	6.16611E 01	6.16633E 01	0	0
15	6.16633E 01	6.16655E 01	1	1.053

CUMULATIVE FREQUENCY DISTRIBUTION

VARIABLE 44

INTERVAL	VALUE	NUMBER LESS THAN VALUE	PERCENT LESS THAN VALUE
1	6.16350E 01	4	4.211
2	6.16372E 01	7	7.368
3	6.16394E 01	16	16.842
4	6.16415E 01	25	26.316
5	6.16437E 01	39	41.053
6	6.16459E 01	50	52.632
7	6.16481E 01	66	69.474
8	6.16502E 01	74	77.895
9	6.16524E 01	84	88.421
10	6.16546E 01	87	91.579
11	6.16568E 01	91	95.789
12	6.16589E 01	93	97.895
13	6.16611E 01	94	98.947
14	6.16633E 01	94	98.947
15	6.16655E 01	95	100.000

```
DSMEAN,44
 44        :   61.64554708
DSSTDEV,44
 44        :   0.006034510
```

Table I. Preliminary analysis of headed and gutted pollock production at Petersburg Fisheries, Spring 1977.

Assumptions

1. The seafood plant has in place facilities for unloading, transporting, packaging, freezing, storing and shipping seafood products.

2. Machinery purchased for pollock production is assigned a useful life of three years and a 50% salvage value (as stated in contract, section 5.5). For simplicity, the annual amortization figure is allocated over the two-month production period for purposes of evaluating this production period only.

3. A 10% opportunity cost of capital was used in amortization of the capital requirements.

4. Total production during the period was 238,000 pounds, round weight.

5. The product weight was assumed to equal 56% of round weight.

6. Again for simplicity, all pollock received was assumed to contain roe, and thus an ex-vessel price of 5¢/lb. was used.

7. The price for headed and gutted pollock was 18¢/lb., fob Jamaica.

8. Pollock roe yield was 3% of round weight.

9. Price received for pollock roe was $1.00/lb.

10. Sales costs are taken to be 5% of revenues received, as specified by contract.

Production Cost Analysis

Capital Requirements

The following machinery was purchased by Petersburg Fisheries for headed and gutted pollock production:

Table I (continued)

1. One Arenco CIV heading and gutting machine, installed price $15,000.00.

2. Conveyors, belts, etc., installed price $2,000.00.

Item	Cost	Amortized @ 10%*	Production Period
Arenco CIV	15,000	3,116	519
Conveyors, belts, etc.	2,000	415	69
TOTAL	17,000	3,531	588

Capital costs/pound raw product = 25¢/lb.

*Annual charge computed using:

$$\text{Annual charge} = \frac{C(1 + r)^n - SV}{\{(1 + r)^n - 1\}/r}$$

where: c = cost of asset SV = salvage value

n = useful life r = opportunity cost of capital

Operating and Maintenance Costs

System	Item	Cost	¢/lb. raw product
Unloading/sorting	labor	6,545	2.75
Transporting	labor	5,950	2.50
Heading, gutting, & roe extraction	labor	11,662	4.90
Packaging	labor	5,950	2.50
Freezing	labor	5,950	2.50
TOTAL LABOR		36,057	15.15
Raw product		11.900	5.0

Table I (continued)

System	Item	Cost	¢/lb. raw product
Power & Water		357	0.15
Packaging	materials	4,760	2.0
Maintenance	materials	450	0.19
Indirect costs	admin., etc.	4,760	2.0
Shipping	freight	4,760	2.0
Sales		1,856	0.78
SUB-TOTAL		28,843	12.12
TOTAL O&M COSTS		64,900	27.27

Total Production Costs

	¢/lb.
Operating & maintenance labor	15.15
Other O&M	12.12
Capital	0.25
TOTAL COSTS	27.52

Revenues

	¢/lb. product weight	Revenue	¢/lb. round weight
H&G pollock	18	23,990	10.1
Pollock roe	100	7,140	3.0
TOTAL		31,130	13.1

Using the above data, and under the stated assumptions, it appears that headed and gutted pollock was produced at a cost of 27.52¢/pound and brought a return of 13.1¢/pound.